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Geothermal contribution on southern Europe climate for energy efficiency of university buildings. Winter season

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Abstract

Geothermal energy production consists of two main types: low temperature or low enthalpy for temperatures below 150ºC, and high temperature or high enthalpy systems for temperatures over than 150ºC. In mainland Portugal the most common ground temperature varies from 20 to 40ºC, depending on the place where the geothermal boreholes are placed, which means that low enthalpy systems can be considered. Currently the increased development of ground source heat pumps (GSHP) lead to a continuous development and innovation of ground heat exchangers (GHE). The geothermal systems can contribute with savings between 25-75% of the energy demands of buildings' HVAC systems, making it a very appealing solution mainly in northern and central Europe. The goal of this paper is to analyse the performance of a geothermal system installed in a department of the University of Aveiro, in the center of Portugal. Firstly, an introduction about different GHE systems is done and after a real case study is described and the methodology applied. To achieve the goal established, the building was analysed, audit and modeled, and an energy simulation was carried out with EnergyPlus® 8.6 (EP) software. After the results obtained it can be concluded that even in regions with mild climate as Aveiro, the geothermal system contributes with 34% of savings of the annual global primary energy needs.

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1. Introduction

1.1. General aspects

Building sector is responsible for over one-third of the global energy consumption [1] and is responsible for one-third of the total greenhouse gas emissions [2]. In 2011, 35% of European CO_2-eq emissions were caused by residential and service buildings [3, 4]. Beyond this concern with this high energy consumption, since the 1970's oil crisis, several voluntary and mandatory certification programs (e.g. BREEAM [5], LEED [6]) and Energy Performance of Buildings Directive (EPBD) [7]) have been developed and introduced at national, regional and international levels to reduce the energy consumption and decrease the adverse environmental impacts of the buildings [8].

In the operational phase of buildings, energy is used for different purposes such as lighting, heating, ventilation and air-conditioning (HVAC - heating, ventilation and air conditioning systems), among others, so, the reduction of the buildings' operational energy is in almost the cases the primary focus of the building energy conservation measures [8]. In fact, this incidence is due by the fact that during buildings' operational phase the amount of energy consumed is much higher than the energy consumed during all the other life-cycle phases [9-11]. Consequently, there is a common concern on buildings' energy use and environmental impact reduction and in the best measures to achieve this. The need to achieve net or near-zero carbon or energy buildings grow up and the European Union published the EPBD [7]. Its main goal is to ensure that in all Member States by the end of 2020 all new buildings will be Nearly Zero-Energy Buildings (NZEBs). EPBD strongly encourages buildings energy efficiency, by the reduction of buildings energy consumption and to a very significant extent covered by energy from renewable sources, including renewable energy produced on-site, like geothermal energy. In fact, despite the great impact of building thermal quality, in university school buildings with high occupancy rates and internal loads, it is unavoidable to use mechanical heating and cooling to provide thermal comfort and wellbeing. This paper aim to present the performance and the contribution of the geothermal system installed in a Research Department of the University of Aveiro, located in the center of mainland Portugal, in a region with mild climate, which goal is the decreasing of the building energy needs both for heating and cooling.

1.2. Ground Heat Exchangers

The increased development of GSHP lead to a continuous development and innovation of GHE [12]. The use of GSHP systems are increasing, because usually offer great advantages at energy efficiency level and at environmental performance, over the traditional systems [13-16]. The main type of GHE have been the borehole, but in recent years, the building pile foundation structure start to include heat exchange pipes, to act as a new type of GHE known as ‘‘pile foundation GHE” or ‘‘energy pile” [17,18]. In this type of GHE the pile diameter is larger than the traditional borehole, and spiral coils rather than U-tubes are usually adopted [19-21]. The heat transfer quantity per meter of energy pile is greater compared with borehole GHE and the GHEs of GSHP system are composed by both borehole and pile foundation GHEs when building`s piles are considered. Both systems have to be considered because energy piles alone are usually insufficient to face the energy needs of the buildings' air conditioning load. This is due because the number of piles is limited, and the surplus load is assumed by borehole GHEs. Pile foundation GHEs are favorable for the development of GSHP system, because the land area needed for borehole GHEs and the initial cost of drilling boreholes get reduced. This space and economic factors lead to pile foundation GHEs have becoming gradually adopted in the engineering projects [12].

In the University of Aveiro until now, five buildings for scholar and research purpose with geothermal systems were constructed. In almost the buildings the geothermal system is composed by both borehole and pile foundation GHEs. But, in the building under study in this paper the system is composed only by boreholes GHEs.

Nomenclature

COP	Coefficient of performance
EER	Energy efficiency ratio