Geothermics 57 (2015) 173–184

Contents lists available at ScienceDirect

Geothermics

journal homepage: www.elsevier.com/locate/geothermics

Empirical modeling of maps of geo-exchange potential for shallow geothermal energy at regional scale

Antonio Galgaro[a,b], Eloisa Di Sipio[b,*], Giordano Teza[a], Elisa Destro[b], Michele De Carli[c], Sergio Chiesa[d], Angelo Zarrella[c], Giuseppe Emmi[c], Adele Manzella[e]

[a] *Department of Geosciences, University of Padua, via G. Gradenigo 6, 35131 Padova, Italy*
[b] *Institute of Geosciences and Earth Resources of National Research Council IGG-CNR Padova, via G. Gradenigo 6, 35131 Padova, Italy*
[c] *Department of Industrial Engineering, University of Padua, via Venezia 1, 35131 Padova, Italy*
[d] *Institute for the Dynamics of Environmental Processes of the National Research Council, via Pasubio 5, I- 24044 Dalmine, BG Italy*
[e] *Institute of Geosciences and Earth Resources of National Research Council IGG-CNR Pisa, via Moruzzi 1, 56124 Pisa, Italy*

ARTICLE INFO

Article history:
Received 6 November 2014
Received in revised form 18 June 2015
Accepted 26 June 2015
Available online 9 July 2015

Keywords:
Shallow geothermal energy
Vertical borehole heat exchanger
Ground source heat pump
Geo-exchange potential
GIS

ABSTRACT

An empirical method aimed at generating maps of potential of geothermal energy exchange for shallow vertical closed-loop systems is proposed here. The method uses both geological and technological information. In particular, the ground parameters that mainly influence the heat transfer in borehole heat exchangers, the energetic parameters driving efficient operations of geothermal systems and heating and cooling requirements of a typical residential building are taken into account. Spatial modeling is carried out in a Geographic Information System leading to an effective and easy-to-use digital cartographic tool. An application of the method to four regions of southern Italy is also shown.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The increasing use of renewable energy resources both for power and heat generation is a valuable tool to overcome the economic dependence on fossil fuels and ensuring energy supply to the standard of today's development. As stated by the Geothermal Energy Roadmap edited by the International Energy Agency (IEA, 2011), in the next future the use of geothermal resource is likely to increase, given its ability to meet part of the global energy needs and to produce low levels of greenhouse-gas emissions (GHG), reducing significantly CO_2 emissions in the atmosphere. The improvement and development of existing technology combined with a better knowledge of the thermal properties of a territory is essential for planning, at national and regional scale, an optimal utilization of underground thermal resources available everywhere.

Shallow geothermal energy and new technologies applications could replace air-source heat-pump systems to reduce the use of conventional energy resources (Nam and Ooka, 2011). In Italy, where over 20% of total energy consumption is due to domestic heating, the use of this renewable energy is being considered to improve with significant impact in reducing the share of greenhouse gas emissions and the reduction of primary energy consumption of buildings (Gemelli et al., 2011; Bayer et al., 2012).

As for any form of energy resource, the estimation of energy potential is fundamental to assess the economic benefits and the management plan of its exploitation. For shallow geothermal energy this requires a reliable quantification of geo-exchange potential of the ground combined with the use of borehole heat exchangers (BHEs) coupled with a heat pump for heating/cooling purposes of residential buildings. Ground source heat pump systems (GSHP) are conceived to extract heat from the ground in heating mode and/or inject it into the ground in cooling mode. Two main categories of GSHPs are commonly adopted, the so-called open-loop systems (OLSs) and closed-loop systems (CLSs). The OLSs are based on use of groundwater as heat carrier fluid, extract from the ground and brought directly to the heat pump in contact with the surrounding environment. The CLSs, instead, use water or a mix of water and antifreeze as heat carrier medium, circulating inside BHEs and in this way physically separated from the rock/soil and groundwater (Bakirci, 2010). The CLSs are becoming increasingly popular due to their ability to be installed virtually anywhere, to be used in heating and cooling mode and to reduce in a tangible way the energy costs related to building conditioning (Ondreka et al., 2007; Busby et al., 2009). Use of GSHPs can be an efficient and environmentally friendly technique for different climatic conditions and in particular in temperate zone, where the practices

* Corresponding author.
E-mail address: eloisa.disipio@gmail.com (E. Di Sipio).

http://dx.doi.org/10.1016/j.geothermics.2015.06.017
0375-6505/© 2015 Elsevier Ltd. All rights reserved.

of heat exchange with the subsoil occurs ubiquitously at 'normal' temperatures in the relatively shallow subsurface (Zarrella et al., 2013; Østergaard and Lund, 2011). For this reason, the present paper focuses on estimating the potential of the CLSs only.

The overall efficiency of a GSHP depends particularly on the heat exchangeable rate with the ground, the energy request of a specific building and correct design of all the components. The heat transfer processes with the ground, as well as the initial GSHP plant costs, which include drilling and piping, are strictly dependent on the geological conditions. Therefore, it is important to accurately estimate the thermal properties of a selected site and predict the heat extraction rate from the ground in order to optimize the design (Signorelli, 2004).

The geo-exchange potential at regional scale can be determined by two main components, the resource and the technical potentials. The former highlights the influence of geology, thermal properties, climatic parameters, groundwater presence and ground temperature at surface on quantifying the heat transfer ability of the subsurface rocks and sediments and on determining the BHE well-sound length. The latter is related to the building type and size, the required thermal load and the adopted technological solution (Yeo and Yee, 2014). For example, the thermal conductivity of rocks affects the size, the average thermal power and the operating temperatures of a BHE (Clauser, 2006).

To understand how to exploit this energy resource and evaluate the geothermal potential at regional scale, the use of cartographic tool is fundamental. Nam and Ooka (2011) studied the macro-availability potential in the 23 wards of Tokyo, in order to make optimal use of GSHPs; Noorollahi et al. (2008) analyzed spatial associations between geothermal exploration and environmental evidence layers using GIS as a decision-making tool to determine the appropriate sites for exploration; Gemelli et al. (2011) presented a GIS-based energetic-economic model of low temperature geothermal energy applied to the Italian Marche region. Busby et al. (2009) discussed some of the geological factors that influence the performance and hence design of a GSHP.

This paper shows a GIS-based approach maps able to generate thematic maps of geothermal energy exchanged potential by vertical boreholes, where both geological and technological information is used. Since the modeling has empirical character, it was applied to four regions of Southern Italy within the framework of the VIGOR Project (VIGOR, 2010) to produce geo-exchange potential maps. The obtained maps are conceived for energy planning purposes at regional scale and, due to the complexity of the different system components (house type, geological conditions, heating/cooling needs), provide a first and rough estimation of the geo-exchange potential of the areas taken into consideration.

2. Case study: geological and climatic setting

Since the proposed method has empirical character, a case must be studied in order to show how it works. In the framework of VIGOR Project four regions of Southern Italy characterized by a Gross Domestic Product (GDP) per capita below 75% compared to the European Community average (the so called "Convergence regions") were chosen in order to promote their development also by means of increasing use of renewable energy. These regions are Apulia, Calabria, Campania and Sicily. They are surrounded by the Adriatic, Ionian, Tyrrhenian and Mediterranean Seas, have an overall surface of around 73,000 km^2 and have more than 17 million inhabitants (Fig. 1). Although the area includes a fifth region (Basilicata), this could not be included in the study and financing initiatives of the VIGOR Project since this region is characterized by a higher level of social and economic development with respect to the other ones and, therefore, was not eligible under the Convergence Objective.

Fig. 1. Case study: the four regions of Southern Italy related to VIGOR Project.

From the geological point of view the south of Italy belongs to the complex structural environment of the Central Mediterranean region, whose origin is related to the opening of the Tyrrhenian Basin and the Africa-Europe plate convergence (Spina et al., 2011).

The central-southern Apennines chain is a nappes structure with thrust faults and folds verging toward the Adriatic Sea, crossed over the Apulian platform. The platform outcrops are dominated by limestone and dolostone sequences overlained by thin Quaternary deposits (Polemio and Lonigro, 2012).

On the Tyrrhenian margin metamorphic units are covered by Miocene flysch deposits and other heterogeneous sediments including evaporites as gypsum and salt deposits (Cavazza and Ingersoll, 2005). Finally, conglomerates, calcarenites and sandstones, marine terraced deposits (Middle–Upper Pleistocene) and alluvial sediments (Holocene) ϵ form the alluvial and coastal plains of the four regions.

The late Pliocene,structural-tectonic processes explain, on one hand, the onset of volcanic phenomena in the Phlegraean Fields, Vesuvius, Eolie and Etna areas and, on the other, the presence of high-grade metamorphic and igneous rocks in Calabria (Bosellini, 2011). The complex geological history of the area is clearly testified by the heterogeneous lithological distribution of outcrops in the four regions (Fig. 2).

From a climatic point of view southern Italy is characterized by a temperate Mediterranean climate. In detail, the four regions considered in the study are characterized by dry and hot summers with temperatures sometime exceeding 40 °C and mild winters, particularly along the coasts (Claps et al., 2008). During winter season in coastal areas the mean temperature rarely drops below 12 °C, whereas in the Apennines chain winters are cold and snowy with temperature sometimes below −20 °C. Summers are hot in the valley, progressively cooler at altitude.

3. Method

A new approach to modeling maps of geo-exchange potential for shallow geothermal application at regional scale is proposed. The

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات