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Geothermal potential assessment for a low carbon strategy: A new systematic approach applied in southern Italy

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ABSTRACT

In this study a new approach to geothermal potential assessment was set up and applied in four regions in southern Italy. Our procedure, VIGORThermoGIS, relies on the volume method of assessment and uses a 3D model of the subsurface to integrate thermal, geological and petro-physical data. The method thus produces 2D geothermal potential maps for three different uses: district heating, district heating and cooling, and electrical power production. Our study focused on carbonate reservoirs, which usually present an excellent natural permeability and important geothermal gradients at depth. Our computations were possible thanks to the large quantity of data available from hydrocarbon exploration that largely investigate deep-seated reservoirs. Based on geothermal potential available for power production we estimate the contribution of the geothermal energy in the CO_2 emissions reduction in the study regions. Moreover policy makers as well as investors can use our maps to establish new policies and to locate the most promising places for geothermal development, in line with the international low carbon strategy.

1. Introduction

Economic development is strongly correlated with increasing energy use and the related rise of GHG (greenhouse gas) emissions. The use of RE (renewable energy) can help decouple this correlation, thus contributing to sustainable development.

The ratified Kyoto Protocol in 2005 [1], establishes the future target GHG cap emissions for different countries in the future, compared to 1990 levels, resulting in GHG emission reductions by 20% in 2020 and 50% in 2050 respectively.

To meet these challenging targets, many international organizations and governments are promoting the use of renewable energy in the private and public sectors.

Geothermal energy, the renewable with the most secure base-load and low GHG emissions [2], supplies heat for direct use and energy for power production. In the last century, heat from the Earth's interior has been used in 25 countries for electricity production, with an estimate of 73.5 TWh/yr of supplied energy provided in 2015 [3]. In addition 82 countries are using the direct heat, for heating and cooling, generating 163.2 TWh/yr of thermal energy to 2015, including GHP (geothermal heat pump) applications [4].

Geothermal energy can play a significant role in the abatement of GHG emissions, yielding up to 4% of future energy consumption (power and heat) [2,5].

Most of the actual production is deployed from hydrothermal reservoirs, made of underground fluid-filled rocks where fluids are heated by the natural heat of the earth and are brought to the surface by means of wells.

The known high temperature (above 180 °C) hydrothermal resources occur only in few places in the world, usually volcanic and magmatic areas. However, the optimization of technologies able to co-produce power and heat from hydrothermal systems of medium temperature (usually in the range 110–180 °C) has produced an impressive increase of geothermal plants from medium-temperature resources in non-volcanic areas.

Geothermal energy can be developed economically and at low risk, when targeting naturally permeable reservoirs, which have

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been explored (and exploited) extensively over the past decades by the hydrocarbon industry. This is clearly demonstrated in the Netherlands, where over 10 geothermal heat plants have been developed in the last 10 years in sandstone reservoirs at 2–3 km depths, thanks also to public access to data and subsurface models [6].

Apart from sandstone, (fractured) carbonate reservoirs have considerable geothermal potential [7,8,9], as they have excellent natural permeability for geothermal development and the cogeneration of heat and power from reservoirs at great depths (see research projects such as GeoMol [10], and deployment projects such as Traunreut [11], Taufkirchen [12], Unterhaching [13]).

2. Objective

In this paper we highlight the significance of these geothermal resources in a case study in southern Italy, characterized by a widespread abundance of carbonate units up to great depths. The formations present a variety of subsurface temperature gradients which are representative for non-magmatic areas, measured in the frame of oil and gas exploration.

The last geothermal potential assessment in Italy was carried out at the end of the 1980s with the completion of the Inventory of the Italian Geothermal Resources. This involved a joint venture including ENEL, ENI, ENEA and CNR, and published by Cataldi et al. [14]. In the assessment, Italy was divided and ranked in seven categories on the basis of the presence of a regional aquifer of up to 3 km depth and on the temperature range of the fluid. However, this survey failed to clearly identify the carbonate potential reservoirs. Moreover, a quantitative geothermal potential has never been established in Italy, and the few available estimates [[15] and references therein] are based on semi-quantitative assumption.

In this paper we propose a new approach to the geothermal potential assessment through a resource assessment built from a voxet[1] based subsurface representation of rock properties and a comprehensive techno-economic evaluation of prospectivity [16,17]. The resulting procedure, named VIGORThermoGIS, produces geothermal potential maps on the basis of the thermal energy needed and the availability of suitable carbonate reservoirs underground.

This procedure was set up in with the framework of the VIGOR project aimed at assessing the regional geothermal potential in four regions of southern Italy: Apulia, Calabria, Campania and Sicily. The computation was applied to the regional on land geothermal reservoir, thus minor volcanic islands and off-shore areas were not considered.

3. Methodology

The most commonly-used method for geothermal potential assessment relies on volumetric approaches by estimating the thermal energy available in a deep-seated reservoir and the recoverable fraction suitable for the exploitation from technical and/or financial perspectives. The principles of the volume method have been widely discussed and applied by several authors since the 1970s [18–26] above all to assess the geothermal potential in hydrothermal systems. The volume method was subsequently revised and reused in order to compute the geothermal potential for EGS (Enhanced Geothermal Systems) in several countries [27–30, 17, 31–33].

[1] A Voxet is defined as a regular gridded subsurface 3D model, consisting of brick-shaped hexahedra.

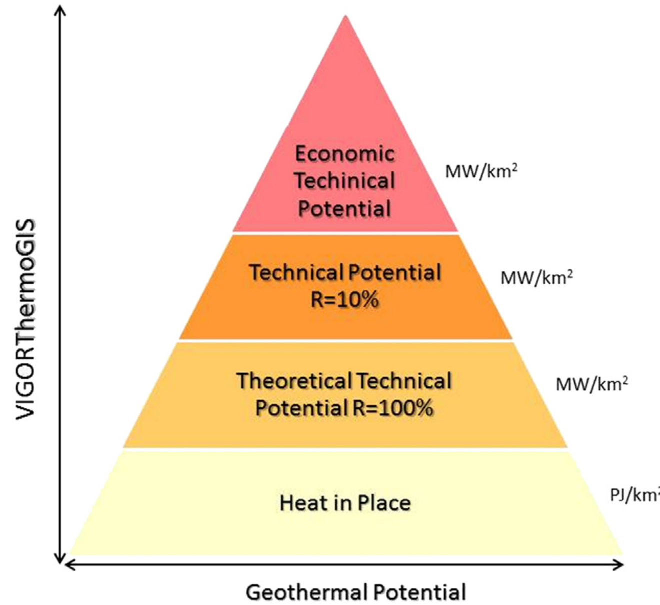

Fig. 1. Progressive geothermal potential filtering, from the Heat in Place to a more realistic Economical Technical Potential.

The geothermal potential assessment in southern Italy was performed by setting up a procedure (VIGORThermoGIS) based on the volume method. The procedure takes into account the practices set up by TNO to assess the prospective areas for geothermal development in the Netherlands (ThermoGIS) [34]. ThermoGIS aimed to evaluate the geothermal potential over several stacked siliciclastic reservoirs. The code was also used within the framework of the GEOELEC project [35] to perform geothermal EGS potential in Europe [36,17]. To address specific features of the geological and geothermal framework in southern Italy, we updated the existing ThermoGIS code. Our assessment focused on the deep geothermal resources, limited to a maximum depth of 5 km below sea level. Such resources are usually hosted in the main regional carbonate units [37]. Below such depth, at the actual drilling cost geothermal exploitation would be not economically feasible (drilling technology is not so limited, and proved up to 10 km).

The VIGORThermoGIS uses a 3D model of the subsurface represented by a voxet with cells (i.e., voxels), with a typical horizontal resolution of 1 km and a vertical resolution of 100 m.

The procedures compute the geothermal potential on the basis of three main components: i) the resource, considering the geometry and the petrophysical properties of the reservoir, ii) the application, which includes in the assessment the specific application technology features and iii) the finances involved, which ensures the energy production estimation taking into account the costs for energy production.

The resource is defined by the geometry of the reservoir, the temperature distribution in the subsurface, the expected rock permeability, and the thermal properties of the fluid-rock system.

VIGORThermoGIS provides a series of geothermal potential maps, such as a heat in place map (H), a technical potential map (TP), and an economic technical potential map (ETPlcoe).

The EPP (electric power production) with binary plant, DH (district heating) and DHC (district heating and cooling) applications were considered in this study. Other typical applications for the direct use of the heat were not taken into account as the regional geothermal reservoir is located at an uneconomical depth.