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Environmental and social aspects of geothermal energy in Italy

Adele Manzella[a,*], Roberto Bonciani[b], Agnes Allansdottir[c], Serena Botteghi[a], Assunta Donato[a], Silvia Giamberini[a], Alessandro Lenzi[b], Marco Paci[b], Anna Pellizzone[a], Davide Scrocca[d]

[a] CNR—Institute of Geosciences and Earth Resources, Via Moruzzi 1, 56124 Pisa, Italy
[b] Enel Green Power, Via Andrea Pisano 120, 56122 Pisa, Italy
[c] Fondazione Toscana Life Sciences, Via Fiorentina, 1, 53100 Siena, Italy
[d] CNR—Institute of Environmental Geology and Geoengineering, c/o Dip. Scienze della Terra Università Sapienza, P.le A. Moro 5, 00185 Roma, Italy

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ABSTRACT

Geothermal plants have been producing power in Italy for more than a century. Since local opposition to geothermal development is often fuelled by incomplete and inaccurate environmental information, this paper provides a comprehensive description of the effect of geothermal development on the air, water and soil and investigates potential disturbance from noise, subsidence, and seismicity, as well as the visual impact on the local area. After discussing the risks associated with the geothermal development and the reference data, the paper describes the wide-reaching environmental monitoring and mitigation measures in Italy that have maintained impact values below the thresholds defined by European and Italian regulation. The social benefits for areas where geothermal energy is developed are also described, with the aid of case studies highlighting that citizens do not feel that they are sufficiently informed to have a voice in the innovation process. A regular and comprehensive review of the geothermal environmental and safety regime, as the one carried out in this paper, and a mutual exchange of knowledge between the different stakeholders should be strongly encouraged.

1. Introduction

Geothermal resources are abundant in Italy, ranging from resources for shallow applications (including heat pump technology), through to medium (> 90 °C) to high (> 150 °C) temperature systems at depths accessible only by wells (usually within 3–4 km). High temperature systems tend to be in tectonically active regions either in volcanic and intrusive or fault-controlled systems (Santilano et al., 2015 and ref. therein).

Geothermal resources are today mainly used for generating electricity and air conditioning by means of district heating (DH) and geothermal heat pump systems. The DH systems are mainly located in Tuscany in central Italy, and direct uses are common. The heat delivered by direct geothermal uses is 10,500 TJ generating 1300 MWth, with about half of the installed capacity being for space heating (DHs and individual systems) (Conti et al., 2016).

Geothermal energy is the third thermal renewable energy source in Italy, after bioenergy and air-source heat pump systems, and supplies about 2% of the total renewable heat consumption. Thermal balneology was once very popular and until 2010 was the first sector of utilization but the number of customers has since fallen by about 5% (Conti et al., 2016). In total, the estimated capacity of geothermal direct uses in 2015 was 1300 MWth, GSHP accounting for 42% (about 580 MWth), followed by thermal balneology (32%), DH (10%), fish farming (9%), agricultural (6%), and industrial uses (1%) (Conti et al., 2016).

Italy was the first country in the world to produce electricity from geothermal fluids and is Europe's top generator of electrical power from geothermal resources (sixth in the world) (Bertani, 2016).

All of the 34 power plants in operation (by Enel Green Power) in Italy are located in Tuscany, a region in central Italy, in the two "historical" areas of Larderello-Travale and Mt. Amiata (Fig. 1). The net electricity generation was 5871 GWh in 2016 (TERNA, 2016a). The installed capacity in Larderello and Mt. Amiata is 795 MWe and 121 MWe, respectively. In Italy geothermal power production has increased continuously due to the resources being managed effectively. After an initial exploitation of the shallow carbonate reservoir, limited to 1 km depth, the fluid production was increased thanks both to the positive results of deep drilling that revealed a reservoir hosted in the deep crystalline (metamorphic and granitic) rocks, and to the effects of the reinjection of separated water and condensed steam into the reservoirs. Geothermal contribution to electrical energy capacity in Italy is 1%, and 2% to the overall demand for energy (TERNA, 2016b).

Various legislation has regulated research into and the usage of geothermal energy in Italy.

* Corresponding author.
E-mail address: manzella@igg.cnr.it (A. Manzella).

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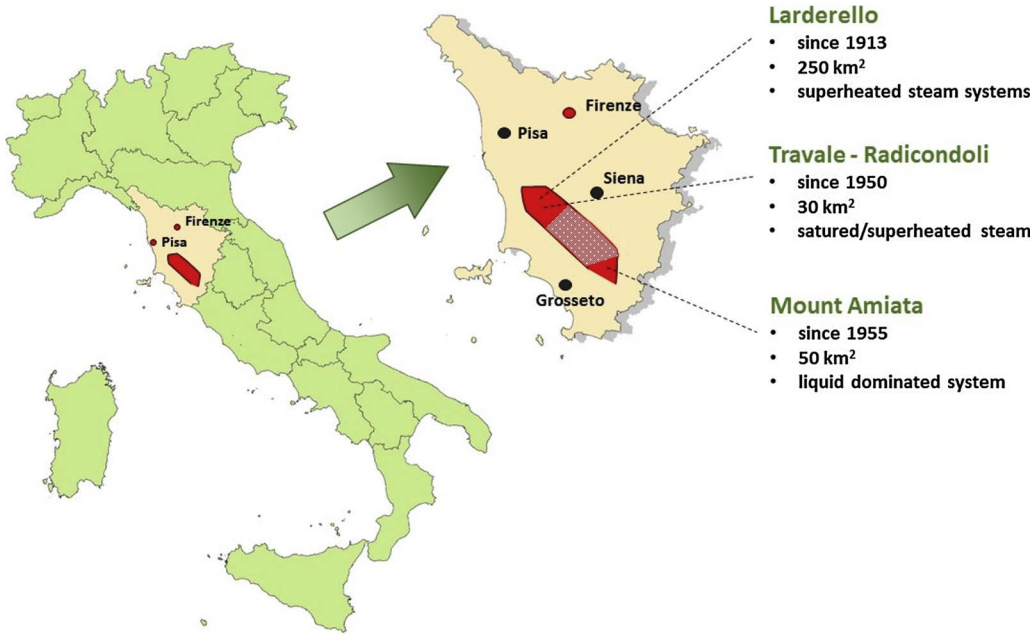

Fig. 1. Location of the geothermal areas producing electrical power in Italy.

In 2010, an LD liberalized research and exploitation of geothermal resource, and applied incentives for renewable sources. This led to several new players trying to enter the market, with about 120 new applications for new research permits in geothermal resources suitable for power generation, cogeneration and district heating. After this initial rush, only a few proposed projects completed the surface exploration and in most cases the Environmental Impact Assessment (EIA) procedure required for the mining lease is still ongoing.

This slowdown is partly due to the change in the electricity market and the support for renewable energies. In 2013 "Green Certificates" were replaced by an "Incentive Fee" similar to an all-inclusive fee decreased by the zonal price of energy to which additional premiums can be added. The value of the net kWh generated from new or recent geothermal power plants passed from about 13.7 Eurocent/kWh awarded with "Green Certificates" to 9.9 or 8.5 Eurocent/kWh with the new "Incentive Fee", for units with an installed capacity under or above 20 MWe, respectively (Conti et al., 2016).

Another reason for the slow development of new geothermal projects is the issue of social acceptability for some local communities who are concerned by environmental issues. The first formal national guidelines for defining environmental features related to geothermal development were released in July 2016, and described the best practice to be followed in the most important phases of a geothermal project, in particular for those related to electrical power generation and requiring the drilling of deep wells (MISE-MATTM, 2016).

In this paper, we outline the environmental aspects of geothermal development in Italy, the associated risks, the reference data and the adapted form of mitigation and/or abatement measures. We focus on the potential impact related to the development of geothermal power production, since for other applications the potential impact is negligible or, in any case, a subset of those here discussed. Indeed, geothermal fluids used for power production are, both in terms of chemical composition, temperature and pressure, those requiring the highest level of safety procedures in their management. In addition, while there are considerable reliable data for geothermal power production, little is available for other applications.

All phases of a geothermal project can potentially produce environmental impacts, including exploration e.g., active seismic exploration methods. However, we will focus only on those phases specifically related to geothermal plant development. The main activities causing an environmental impact are related to:

- Building of access roads and drilling pads
- Well drilling, well repairs, and well testing
- Laying of pipelines, electric power transformation and transmission lines
- Plant construction and installation of equipment
- Power plant commissioning and operation
- Decommissioning of facilities

Before giving a detailed description of the environmental aspects, we first summarize the power production technologies used in Italy, thereby introducing some of the most technical terms which will then be used in the following sections.

2. Electricity generation technologies

Almost all the power plants in operation in Larderello-Travale and Mt. Amiata are based on direct cycle or flash cycle technologies, depending on the nature of available geothermal fluid which in these areas can be superheated steam, saturated steam or two-phase fluid with an NCG (Non-Condensable Gases) content of about 2–10% wt.

In the direct cycle technology, the steam (see Fig. 2) comes from production wells or flash stage, and is fed directly into a steam turbine. After the steam expansion, where power is produced, the steam is condensed in a mixer condenser through the use of cooling water. The condensed steam and the cooling water are then fed to a wet cooling tower (normally three cells are used for a standard 20MWe unit) where the water is cooled and the condensed steam is partially stripped and emitted with the heated air (about 50–70% of the inlet flow). Stripped condensed steam and water drops of various dimensions (known as *drift*) are then released into the atmosphere, and contain components already present in the original geothermal fluid. The most recent cooling towers are equipped with a drift eliminator, which guarantees drift emissions lower than 0.1 m^3/h. The remaining part of condensed steam flow (about 30–50%) is injected into the reservoir. In the mixer condenser, the gas is separated from the condensed steam and is fed, through a gas extractor, to an abatement system. The first abatement system was installed in Italy in 2002 (Baldacci, 2004).

Various technologies are available for abating hydrogen sulphide, both upstream and downstream of turbines, as described by Rodríguez et al. (2014). In all the power plants in operation in Italy, NCG is treated downstream of the turbine and of the condenser with AMIS systems that