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Geothermal electricity generation in Italy: status and perspectives

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ABSTRACT

The status of geothermal development for power generation in Italy as of the end of 1998 is presented. A total of 30 power plants, consisting of 38 units, were installed, totalling an electric installed capacity of 728.5 *MW*, 25 *MW* of which kept as a reserve and with 40 *MW* that came on line in 1998. Another power plant, consisting of two 20 *MW* units, was under commissioning at the same time. 1998 yearly generation peaked at an unprecedented maximum of 4.2 billions kWh.

1999 generation should reach a new maximum of 4.5 billions kWh, thanks to the contribution of new power plants, including a 20 MW unit presently under construction, expected to be commissioned in mid-1999.

Geothermal development is currently under way, notwithstanding the uncertainties of the electric sector, being restructured according to the EU regulations.

Plans for the 1999-2004 period foresee the commissioning of a total gross generation capacity of around 330 *MW*, including binary units and the above said 20 *MW* unit already under construction. Over 50% of the new capacity will be made up of power plants replacing almost 180 MW of older units to be decommissioned. Geothermal yearly generation at the end of this program is expected to peak at over 5.5 billions kWh.

Possible further development is dependent on the results of the exploration and drilling activities to be carried out in new areas.

KEYWORDS

Geothermal, generation, electricity, power, Italy

Introduction

It is well known that Italy is the first country where electricity was generated from geothermal resources, the first successful experiments dating back to 1904 and the first commercial power plant to 1913 (Burgassi, 1987). A substantial increase of the installed

capacity took place in Larderello area and surroundings, starting fiom the mid-1930s and continuing in the following years, with the parenthesis of **WW II,** when the plants were destroyed and subsequentlyrebuilt.

In the 1950s, geothermal development was extended to other areas of Tuscany, thus allowing a significant increase in the generated electricity until the late 1960s. The 1970s were a period of stagnation, during which the generation from the new plants made up for the decline of Larderello field.

Only in the 1980s an acceleration in the exploitation of geothermal resources was started by Enel, at that time the Italian National Electricity Board and the only owner and operator of geothermal power plants, utilising the results **of** the exploration work previously made.

The use of standardised power plants **of** 20 **MW** size, featuring an extended degree of flexibility, so as to he fed by steam within a wide range of characteristics (Allegrini et al., 1985), was then introduced and has since been maintained, although with later improvements ("second generation" 20 MW power plants have been introduced in the mid-1990s).

Only in the central part of Larderello field larger capacity plants were used, with three 60 **MW** units installed in the framework **of** the renovation **of** the old geothermal installations, dating back to 1946-1950.

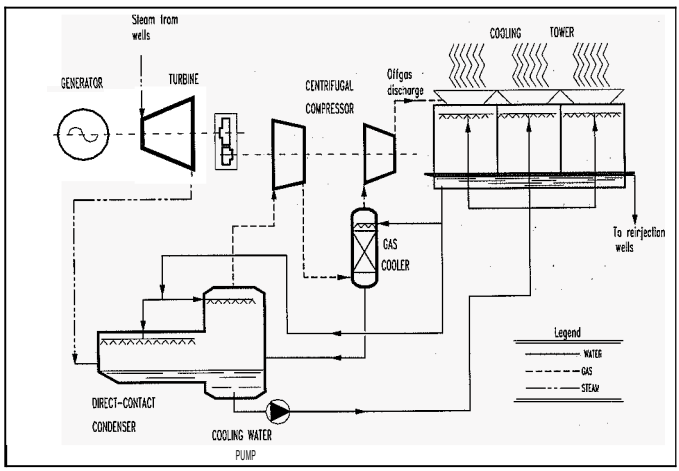

***Figure** 1: Simplified flow scheme of an Italian geothermalpower plant.*

The most interesting feature of Italian power plants is linked to the high NCG (non-condensable gas) content of the steam (typically 3-8% by weight). According to the simplified flow scheme shown in Figure 1, multistage centrifugal compressors (of the integrally geared type in the more recent plants) are used to extract the gas from the condenser. Compressors are directly driven by the turbine (at the opposite end of the generator coupling), with a significant advantage in terms of overall efficiency.

Present status

Generation

Geothermal power plants installed as of the end of 1998 are listed in Table 1. According to their geographical location, they are grouped in the following areas (all of them in Tuscany, see Figure 2):

- Larderello (includes the area exploited for the longest time and the Southernmost part of the field, often referred to as "Val di Cornia")
- Travale-Radicondoli (East of Larderello)
- Mt. Amiata (in Southern Tuscany, where the fields of Bagnore and Piancastagnaio are located).

Table 1 shows a number of 30 installed power plants, totalling 38 units and 728.5 MW, among which 18 are standardised 20 MW units, with two of them commissioned in 1998 (Carboli 1 and Bagnore 3). Two units (12.5 MW each, in Lago and Serrazzano plants) are kept as a reserve, while Bagnore 2 plant, presently not in operation, will be restarted in the year 2000 after upgrading works.

Yearly generation peaked at an unprecedented maximum of 4.2 TWh in 1998 (it had reached 3.9 TWh in 1997). Total yearly steam consumption was over 34 million metric tons; around 30% of the extracted fluid was reinjected.

Comparative figures as of the end of 1994, presented at the 1995 World Geothermal Congress in Florence (Allegrini et al., 1995) and reported here for comparative purposes, were an electric installed capacity of 625.7 MW and a generation of 3.4 TWh.

A brief description of each geothermal area and of the activities carried out in it follows, assuming as a reference the situation described in the previously cited WGC paper.

LARDERELLO

The oldest and largest field, with an explored area that reaches 270 km^2, has a total of 172 production and 18 reinjection wells connected to the power plants in operation. Around 3000 t/h of steam are produced, at pressures ranging from 2 to 15 bar and temperatures from 150°C to 260°C; the NCG content varies from 1% to 15% by weight.

Table 1: Utilization of geothermal energy for electri ' generation as of January 1999

Geothermal field	Power plant	Unit	Year commis-sioned	Status	Type of unit	Installed capacity MW_e	998 Electricity generation GWh
.arderello	Valle Secolo	1	1991	O	DS-C	60	444.2
		2	1992	O	DC-C	60	425.1
	Gabbro	1	1969	O	DS-C	15	116.1
	Castelnuovo V.C.	1	1946	R	DS-C	11	0.0
		2	1948	O	DS-C	11	8.6
	Farinello	1	1995	O	DS-C	60	409.2
	Lago	1	1960	O	DS-C	6.5	30.5
		2	1960	R	DS-C	12.5	0.0
		3	1964	O	DS-C	14.5	21.6
	Cornia	1	1987	O	DS-C	20	95.1
	Cornia 2	1	1994	O	DS-C	20	125.3
	San Martino	2	1985	O	DS-C	20	78.2
		3	1988	O	DS-C	20	141.7
	Molinetto 2	1	1982	O	DS-C	8	56.0
	La Leccia	1	1983	O	DS-C	8	60.5
	Lagoni Rossi 3	1	1981	O	DS-C	8	49.2
	Montemtondo	1	1958	O	DS-C	12.5	105.5
	Nuova Sasso	1	1996	O	DS-C	20	116.7
	Serrazzano	1	1957	O	DS-C	12.5	72.8
		2	1957	O	DS-C	12.5	69.9
		5	1975	O	DS-C	15	59.7
	Le Prata	1	1996	O	DS-C	20	128.9
	Monteverdi 1	1	1997	O	DS-C	20	77.8
	Monteverdi 2	1	1997	O	DS-C	20	97.1
	Carboli 1	1	1998	O	DS-C	20	96.7
	Carboli 2	1	1997	O	DS-C	20	106.8
Radicondoli	Pianacce	1	1987	O	DS-C	20	120.9
	Rancia	1	1986	O	DS-C	20	136.4
	Rancia 2	1	1988	O	DS-C	20	144.6
	Radicondoli	1	1979	O	DS-C	15	102.5
		2	1979	O	DS-C	15	103.4
Mt. Amiata	Bagnore 2	1	1962	NO	DS-D	3.5	0.0
	Bagnore 3	1	1998	O	DS*-C	20	2.0
	Piancastagnaio 2	1	1969	O	DS*-D	8	33.5
	Bellavista	1	1987	O	DS*-C	20	118.6
	Piancastagnaio 3	1	1990	O	DS*-C	20	158.0
	Piancastagnaio 4	1	1991	O	DS*-C	20	152.2
	Piancastagnaio 5	1	1996	O	DS*-C	20	148.4
TOTAL	30	38				728.5	4213.1

Status: O= Operational
R= Reserve capacity
NO= Not operational

Type of Unit: **DS=** Dry steam
DS*= Entrained water separated at wellhead
C= Condensing
D= Discharging **to** atmosphere

Reinjection of the steam condensate, begun in the late 1970s, has been very successful, allowing to increase reservoir pressure and steam production, especially in the most depleted areas.

Deep wells (3000-4000 m) were drilled to increase steam production in the known areas and to extend the borders of the exploited part of the field. The existence of permeable

layers within the metamorphic basement was thus proved, which produce superheated steam at high pressure and temperature (up to 70 bar and 350°C at bottomhole), often characterised by a considerable volatile chloride content that makes abatement systems necessary to avoid corrosion problems in the steam pipelines and in the plants.

Renovation of the plants located in the older part of the field was completed with the commissioning of the third 60 MW unit (Farinello power plant). Nuova Sasso 20 MW unit replaced the old Sasso Pisano plant. Five new 20 MW units (Le Prata, Monteverdi 1 & 2, Carboli 1 & 2) were installed in the south-westem part of the field, extending the borders of the exploited area.

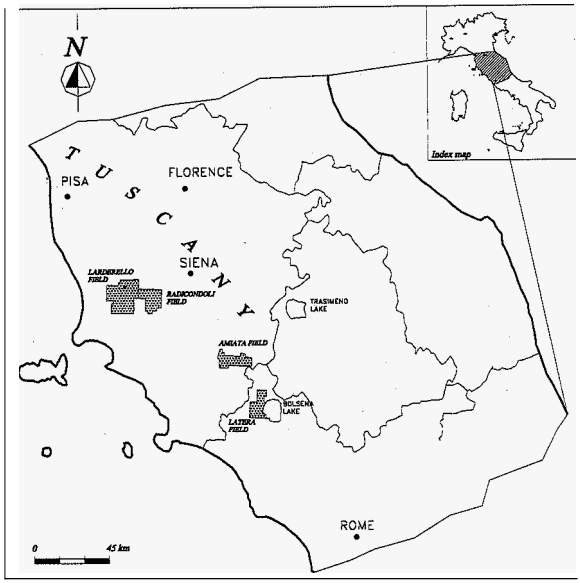

Figure 2: Location of geothermalpower plants in Italy.

TRAVALE-RADICONDOLI

17 production and 2 reinjection wells are in operation in an area of 30 km^2, where 500 t/h of steam (9-16 bar, 200-220°C and 4-8% NCG) are produced. Recent developments allowed to extend the exploitable area to the South.

Deep exploration gave the results very similar to those of Larderello field as far as the physical and chemical characteristics of the steam are concerned and the depth (3000-4000 m) of the permeable layers. Based on these data, it can be said that Larderello and Travale-Radicondoli belong to the same deep geothermal system.

MOUNT AMIATA

Bagnore and Piancastagnaio fields were discovered between the late 1950s and the early 1960s, when wells were drilled in the shallow carbonate reservoir. More recent deep exploration revealed in both cases the existence of an underlying water-dominated reservoir in the metamorphic basement (at depths of 2500-4000 m), with a hydrostatic pressure of 200 bar (at 3000 m) and temperatures of 300-350°C.

All 20 MW units are fed by the steam separated at wellhead (at 20 bar) from the two-phase mixture produced by the deep reservoirs and containing 7-15% by weight of NCG.

Piancastagnaio plants, located in an area of almost 50 km^2, are connected to 17 production and 7 reinjection wells. Around 700 t/h of steam are used. The new 20 MW unit of Piancastagnaio 5 was the latest addition to the generation park.

Bagnore area covers 40 km^2. As gathering systems are still under construction, only 2 production and 1 reinjection wells are presently used by the newly commissioned (at the end of 1998) Bagnore 3 plant (20 MW).

Drilling for power generation

All the wells drilled by Enel in the period 1995-1998 were aimed at the research of steam for power generation, except for a few cases, when the target was to obtain reinjection wells.

30 new wells were completed, totalling around 90 km of length. Almost half of them (14) were located in Larderello area, 6 in Mt. Amiata and 3 in Travale-Radicondoli. The remaining 7 wells were drilled in the framework of deep exploration projects of new areas. A production capacity estimated at around 700 t/h of steam was obtained.

Moreover, a total of 33 wells had a work-over (in some cases the removal of cement plugs) or were deepened, the latter amounting to around 1.5 km of length.

Generation development

At the beginning of 1999, Latera power plant (2 x 20 MW) was being commissioned. It is the first commercial geothermal plant outside Tuscany, being located in Northern Latium, and the first Italian plant to exploit a water-dominated reservoir at an intermediate temperature. The temperature of the aquifer is in the range 210-240°C, featuring 10-12 g/l of TDS and a high NCG content (around 5% by weight). 5 production and 5 reinjection wells are already available.

While in the high-temperature reservoirs of Mt. Amiata (Piancastagnaio and Bagnore) the amount of entrained water accompanying the steam at wellhead is comparatively small and can be disposed of by reinjection, in Latera water prevails in the two-phase mixture produced by the wells, so that it must be used before reinjection.

According to the results of production tests carried out in the 1980's, a flashed steam cycle featuring an upstream direct-contact reboiler was chosen (Latera being the first commercial application of this technology world-wide), due to the high NCG content of the brine (Sahatelli and Mannari, 1995).

Generation from Latera brine will be increased by the addition of 5 MW bottoming binary units (cooling down the spent flashed brine before it is reinjected), expected to come on line by the end of 1999. The recovery of the pressure energy of the NCG separated by the upstream reboiler by means of a tnrhine expander will generate an additional 3.6 MW starting in the year 2000 (this project has been partially funded by the Commission of the European Communities in the framework of the "Thermie" program).

Selva 1 power plant (20 MW), located in the southern part of Larderello field, was also under construction and will be commissioned by mid-1999.

Thanks to the contribution of these new plants, 1999 generation should reach the new maximum of 4.5 TWh.

The 2000-2004 construction plan foresee the commissioning of a total gross generation capacity of 310 MW (corresponding to an installed capacity of around 360 MW). About 40% of this capacity will come from new developments, while the remaining 60% will be made up of power plants replacing almost 180 MW of older units to be decommissioned. These renovations, all in Larderello area but 30 MW in Travale-Radicondoli, will allow an increase of 15% of the electricity generation, using the same steam available, thanks to the efficiency increase.

Apart from renovation programs, only one new power plant (20 MW) is planned in Larderello area (in the southern part of the field). Most of the new capacity will be installed in Travale-Radicondoli (four 20 MW units) and in Mt. Amiata (one 20 MW unit in Bagnore field and the replacement of an existing 20 MW plant with a 35 MW unit in Piancastagnaio field).

At the end of the aforementioned development program, geothermal generation capacity is expected to exceed 5.5 TWh/year, thus marking a 60% increase with respect to the 1994 figure. The average yearly increase of electricity generation corresponds to 5%.

Perspectives

The development of geothermal generation is conditioned by the provisions of the recent decree concerning the restructuring of the electricity sector in Italy according to the EU regulations.

The decree states that, starting from the year 2001, all the importers or producers of

electricity from conventional sources must generate or purchase a share of electricity generated by new plants using renewables. At present, the share is fixed at 2% of the conventional electricity generation plus import, and might be revised from the year ***2003.***

This mechanism creates a competitive market for the "green" energy, which can substitute the previous policy of premium prices for the electricity from renewahles. As a consequence, geothermal development will he strongly influenced by its success in this competition.

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