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Geothermal Power Generation in Italy 2000–2004 Update Report

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ABSTRACT

The geothermal activities carried out in Italy for power production in the last five years (2000–2004) are outlined in this paper.

In Italy geothermal energy is mainly used to produce electricity, and in 2004 was celebrated the centenary of the first experiment carried out at Larderello in 1904. In the same area the first industrial power plant was put in operation in 1913, and since then geothermal power production has progressively increased reaching 790.5 MW installed capacity (699 MW operating capacity) as of December 2004. Electricity generation peaked to a maximum of 5.3 billion kWh in 2003. Ten new power plants, for 254.5 MW installed capacity, have been commissioned and started up in the last five years. Most of these units replaced old plants in operation from many years and considered obsolete.

A new extensive deep exploration program in the areas of Larderello-Radicondoli-Montieri has been launched in 2004 and include 3D seismic surveys and 11 exploratory wells 3000-4000m deep.

Serious acceptability problems from local communities have hindered further developments in the Mount Amiata area, and have forced to stop the operation of the Latera plant, located in Northern Latium.

An innovative plant for Hg and H_2S abatement has been designed by Enel and it is now in operation in some units.

An extensive program for the installation of such plants in the other sites is in progress. Over the last five years, 21 wells have been drilled, totaling 63800 meters, and investment in geothermal research, development and utilization was about US$ 400 million.

1. THE ELECTRICITY MARKET IN ITALY

The liberalization process of the electricity market in Italy has almost been completed.

In line with the European Directive (EC/96/92) relating to the creation of a single market for electric energy in Europe, on 19 February 1999 the Italian Government approved a decree law (n° 79/99) defining the basic rules for the new organization of the Italian electricity market.

According to the new regulations, no individual operator was allowed to generate or import more than 50% of the domestic overall consumption of electric energy as from January 1st, 2003.

In order to comply with this new legislation, Enel S.p.A. sold 15,057 MW of its generating capacity to other operators in the period 2001-2003.

As a consequence, several international competitors are now present in the Italian electricity market.

From April 1st, 2004 the Italian Power Exchange is operating and in the same year an independent private company, called TERNA, was established for the ownership and management of the national high voltage electric grid (transmission network).

The current and planned (2010) electricity generation capacity and production in Italy is summarized in Table 1. Whereas the geothermal data are updated to 2004, the data related to the other sources refer to the year 2002.

The electricity generation from different sources is given in Figure 1.

Specific policies for supporting the development of renewable resources have been adopted in Italy. Under the same law (n° 79/99), as from the year 2001 all operators (importers and producers of electricity from non-renewable sources) have to supply a quota of their production from renewable sources into the grid within the following year. The quota was initially, i.e. from the year 2002, set at 2% of the total energy, produced or imported, exceeding 100 GWh (excluding cogeneration, auxiliary consumption and exports).

Applied to the whole Italian market, the 2% quota was at that time equivalent to about 5 billion kWh. This amount was large enough to spur the market effectively, considering that it had to be obtained only from plants that began production or were re-powered (for the additional capacity only) after the law had come into effect.

The conceived mechanism provides a great deal of flexibility: operators are allowed to meet their obligations either by generating directly or by purchasing from others some or all of the necessary “green” energy, or simply their rights (as in the spirit of the “green certificates”).

In 2003 a new decree law (n° 387/03) fixed a 0.35% per year increase rate for this quota, as for the 2004 – 2006 period, and further increases are foreseen in the subsequent years to keep up with international commitments for CO_2 emissions reduction.

In the first two years of application, this mechanism has lead to an average market price of 8.3 Eurocent/kWh of the so-called “green certificates”, to be added to the average price for the sale of electricity, which has been around 5 Eurocent /kWh.

Since 2002, Enel strategy changed and re-focused toward the core business, i.e. production and distribution of electricity and gas.

The entire renewable sector was therefore moved into the Generation & Energy Management Division, where a Business Area for Renewable Resources was set up. This Business area includes the Geothermal Production Unit, with the mission of developing and operating the geothermal resources for power generation in Italy. As for the development of geothermal projects abroad, a dedicated function, called International Operation and Business Development, was established within Enel–Corporate.

2. GEOTHERMAL POWER GENERATION: CURRENT STATUS AND DEVELOPMENTS

The first centenary of power generation from geothermal resources has been celebrated at Larderello on July 4th 2004 with an important ceremony, and replaying the experience carried out by the prince Piero Ginori Conti in 1904, when a steam engine supplied by geothermal steam was coupled with a dynamo and allowed the lighting of five bulbs in a boric chemical factory. This experiment marked the beginning of a new industrial activity that, in the second half of the last century, has been developed also in many other countries.

After the first experiment, a 250 kW unit was put in operation in 1913, and, from mid '30s, a rapid and continuous increase of power generation was begun., due to the progressive increase of steam production with deeper wells (some few hundred meters) that crossed the cover formations reaching the top of the carbonate reservoir.

The historical trend of electricity generation from geothermal resources in Italy is given in Figure 2, where two different increase phases are shown: the first in the period from '30s to mid '70s, related to the development of the shallow carbonate reservoirs; the second from the beginning of '80s up to now, when the fluid production has been increasing because of the positive results of the deep drilling activity and the artificial recharge of the shallow depleted reservoirs with the reinjection of the condensed steam and water.

In the year 2003 the electricity production has picked-up to 5340 GWh that represent about 10% of geothermal electricity generation worldwide, as well as 25% of the electricity needs in Tuscany, giving a substantial contribution to the green energy generation in this Region.

As of 31 December 2004, the total installed capacity in Italy reached 790.5 MW (in addition, there are 8 MW classified as "cold reserve" and 20 MW as "retired"). The complete list of plants in given in Table 2, and considering the real operating conditions of the plants in the different areas (pressure, temperature, non-condensable gas content of the steam) the total running capacity is 699 MW.

In total 32 units are in operation, 22 in the Larderello area, 6 in the Travale-Radicondoli and 6 in the Mount Amiata area.

It's worth noticing that 10 new units, for 254.5 MW installed capacity, have been commissioned and started up in the period 2000-2004, and 8 of these units have been started up in the year 2002, with a huge organizational effort from the Enel personnel.

All 10 units have been installed in the Larderello-Travale/Radicondoli area, and 7 of them (for 174.5 MW) replaced old units, in operation from many years and considered obsolete. The new units being characterized by better efficiency and lower environmental impact.

For this reason, notwithstanding the relevant strong building commitment, the installed capacity, when compared to December 31st, 1999 is practically the same figure, while comparing the energy production in the years 1999 and 2003 the increase is 937 GWh (Cappetti et al., 2000).

In the Larderello area the commissioning of 2 additional units, for 60 MW installed capacity, is already in progress: 20 MW (Nuova Larderello 3) will increase the capacity in the oldest area of Valle Secolo, thanks to the positive results of reinjection that has allowed an increase in the steam production, while a 40 MW unit (Nuova San Martino), located in the southern part of the Larderello field, will replace 2 old units of the same capacity.

All the power plants are remote controlled and operated from a *Remote Control Station* located at Larderello, where 12 people work in round the clock shifts and ensuring a continuous monitoring. In this way, monitoring and analysis of all plant operating parameters are performed, and in addition is possible to shutdown and restart all the units by the Remote Station.

This solution has allowed a better plant operation while dramatically reducing operating costs.

An innovative plant for Hg and H_2S abatement (called AMIS) has been designed and tested by Enel. Mercury removal is obtained by absorption on specific sorbents while H_2S is catalitically oxidized to SO_2 and then scrubbed by using the geothermal waters from the cooling towers. This solution allows the unattended operation while all the functioning parameters are monitored from the Remote Station. Two AMIS plants are already in operation for the gas treatment of three units (80 MW total) and a program for additional installations in the relevant units is in progress, with a total investment of about US$ 50 million.

3. GEOTHERMAL FIELD UPDATE

All the Italian geothermal fields in operation for electricity production are located in Tuscany (Figure 3): Larderello, Travale/Radicondoli, Bagnore and Piancastagnaio (the two latter being located in the Mt. Amiata area). Serious acceptability problems from local communities have forced to stop the operation of Latera plant (2x20 MW) just after a short testing period (the plant is now on decommissioning), and have hindered further developments in the Mt. Amiata area.

The activities carried out over the last five years have been therefore concentrated in the Larderello–Travale/Radicondoli areas, where positive results of deep exploration and reinjection programs, begun in the late 70's (Barelli et al., 1995; Cappetti et al., 1995; Barelli et al., 2000), made it possible to reassess the field potential and plan both development projects (with additional wells and power plants) and renewal projects (replacement of old units with new ones, characterized by higher efficiency and lower environmental impact).

Larderello

The explored area is about 250 km^2, where 180 wells produce some 850 kg/s of superheated steam at pressure

between 2 and 18 bars and temperature ranging between 150°C and 270°C. The non-condensable gas content ranges from 1 to 15% by weight.

The installed capacity is 542.5 MW, with 21 units in operation

Since the late '70s, reinjection and deep exploration programs were begun in this area with the aim of sustaining or increasing steam production. The reinjection of the steam condensate back into the reservoir has been very successful, especially in the most depleted area (Valle Secolo) and made it possible to increase the reservoir pressure and, as a consequence, the steam production (Cappetti et al., 1995).

The deep exploration program demonstrated the presence of permeable layers within the *Metamorphic Basement*, up to 3000- 4000 m depth, with reservoir pressure and temperature increasing with depth up to 7 MPa and 350°C.

The two strategies made it possible to sustain steam production in the areas in exploitation from many years and the developing of a new project.

Seven new units have been commissioned and started up in the last 5 years in the Larderello area, totaling 154.5 MW installed capacity. Six units replaced old units, while a new project has been developed in a marginal area, with deep drillings and the installation of 20 MW (Sesta).

Travale/Radicondoli

The explored area covers approximately 50 km^2; 22 wells produce about 300 kg/s superheated steam at pressure ranging from 8 to 20 bars, and temperature of 190°C to 250°C. The non-condensable gas content is in the range of 4 - 8% by weight.

The installed capacity is 160 MW with 6 units in operation.

Also in this area the deep exploration showed the presence of permeable layers within the *Metamorphic Basement*, at the same depth, reservoir temperature, and pressure of the Larderello area.

Based on the positive results of the deep exploratory wells drilled on the southern margin of this area, a development program was implemented with the drilling of additional deep wells and the installation of a 20 MW unit (Travale 3), followed by a 40 MW one (Travale 4). In the same area, a 40 MW unit (Nuova Radicondoli) was installed to replace two old 20 MW ones.

The Larderello-Travale/Radicondoli deep geothermal system

It must be pointed out that the deep drilling activity has proved that the two old and shallow fields Larderello and Travale/Radicondoli represent the "outcropping" of a unique wide deep (3000-4000m) geothermal system, with about 400 km^2 extension. At about 3000m depth the same temperature and reservoir pressure was found (300-350°C and 6-7 MPa) both inside and in the marginal areas.

In the deep reservoir the fluid is again superheated steam, but characterized by high volatile chloride content (up to 200-300 ppm). Therefore, specific treatment plants have been designed and installed to avoid corrosion problems both inside the wells (in case of wellhead superheating lower than 20°C), and in the surface equipment (gathering system and turbines).

On the basis of the recent and positive deep drilling results a new exploration program has recently been implemented to verify the possibility of a further increase of steam production from the deep layers of the Larderello-Travale/Radicondoli geothermal system.

This program includes 3D seismic surveys in some selected areas and drilling of eleven exploratory wells.

Mount Amiata

This area includes two geothermal fields *Bagnore* and *Piancastagnaio*, discovered between late '50s and early '60s, with wells producing steam from the shallow *carbonate reservoir*. In the late '70s a deep exploration program was begun and the results were very successful in both these fields, revealing the presence of fractured layers at depths ranging from 2500 to 4000 m inside the *Metamorphic Basement* underlying the shallow carbonate reservoir (Bertini et al., 1995). This deep reservoir is *water-dominated*, with a pressure around 200 bars at 3000 m depth and temperature 300-350°C.

The produced fluid is a two-phase mixture that is separated at wellhead at 20 bars; the non-condensable gas content in the steam ranges from 6 to 8 % by weight. Higher values occur in the steam produced from the shallow carbonate reservoir that feeds a back-pressure unit and condensed downstream to supply heat for a large greenhouse plant.

As of December 2004, the total installed capacity is 88 MW, with 5 units on line.

In this area the presence of a high potential deep reservoir has been proved, but serious acceptability problems with the local communities have hindered further developments over the last five years.

4. DRILLING

The drilling activity in the period 2000-2004 has being decreasing when compared with the previous 5 year period; this is mainly due to the stop of operation in the Mt. Amiata and the difficulties in obtaining new mining leases for exploration projects.

During this period, a total of 21 wells were drilled specifically for the electricity generation, with depths between 2,000 and 4,000 m (five of these wells are deeper than 4,000 m)

The summary of the drilling activity carried out is given in Table 6.

5. PERSONNEL AND INVESTMENTS

The number of professional personnel allocated to geothermal activities has been progressively decreasing (especially when compared to the previous five years), as shown in Table 7.

The overall investments are shown in Table 8, and also these values are lower than for the previous five years period.

This reduction is due to the already mentioned contraction of drilling activity and to the consequential reduction in development projects implementation.

6. CONCLUSIONS AND FUTURE PROSPECTS

In Italy the liberalization of the electricity market can be considered completed by now. As for geothermal, the

incentives introduced over the last years (Green Certificates) allowed a further extension of the activities aiming at exploration and development of deep seated geothermal resources.

In the shallow and most depleted areas of the Larderello field reinjection strategy lead to stabilization and even increase in steam production.

Ten new power plants were commissioned and started up in the last five years in the Larderello-Travale/Radicondoli geothermal area, seven of which for the replacement of old units no more in operation because obsolete.

The total installed capacity as of December 2004 was 790.5 MW and the electricity generation picked up to 5,430 GWh in the year 2003, that represents the 25% of the electricity need of Tuscany, the region where all the geothermal fields in operation are located.

A new deep exploration program has recently been implemented in the Larderello-Travale/Radicondoli area to verify the possibility of a further increase of steam production from the deeper part of the reservoir. This program includes 3D seismic survays and drilling of eleven exploratory wells 3000-4000 m deep.

The strong interaction occurring between geothermal activity and territory, taking into account that we operate in Tuscany, has placed serious hindrance to develop new projects.

Aiming at the retrieval of a constructive and mutually beneficial relation with the territory, Enel has set going a number of initiatives with the intent of achieving a reduction of environmental drawbacks and an increase of acceptability.

New design solutions have been envisaged to reduce the noise and visual impact of drilling pads, gathering systems and power plants.

An innovative plant for the abatement of mercury and hydrogen sulfides (called AMIS) was designed and put in operation with very positive results.

On the basis of the programs already in progress, and of the expected positive results from the new deep exploration program, an increase of 100 MW installed capacity can be regarded as a reasonable target by 2010.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICTY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (Wind, Solar, Biomass and Waste)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation In December 2003	790 *	5340	58659	238291	22933	44277	—	—	1967	5956	84349	293864
Under construction in December 2004	60						—	—				
Funds committed, but not yet under construction in December 2004	72						—	—				
Dismantling	40											
Total projected use by 2010	882	6000	67000	278000	23000	58000	—	—	4000	16500	94890	358500

* December 2004

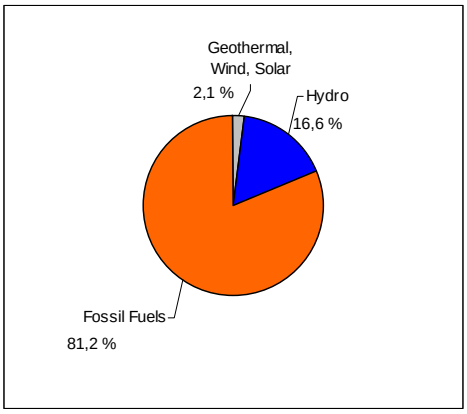

Figure 1: Electricity Generation in Italy (2002)

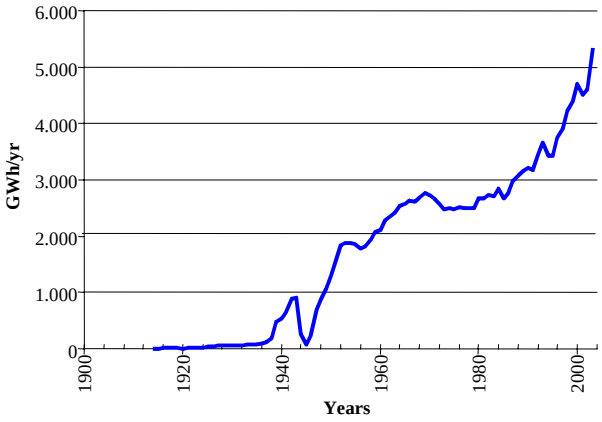

Figure 2: Yearly geothermal power generation

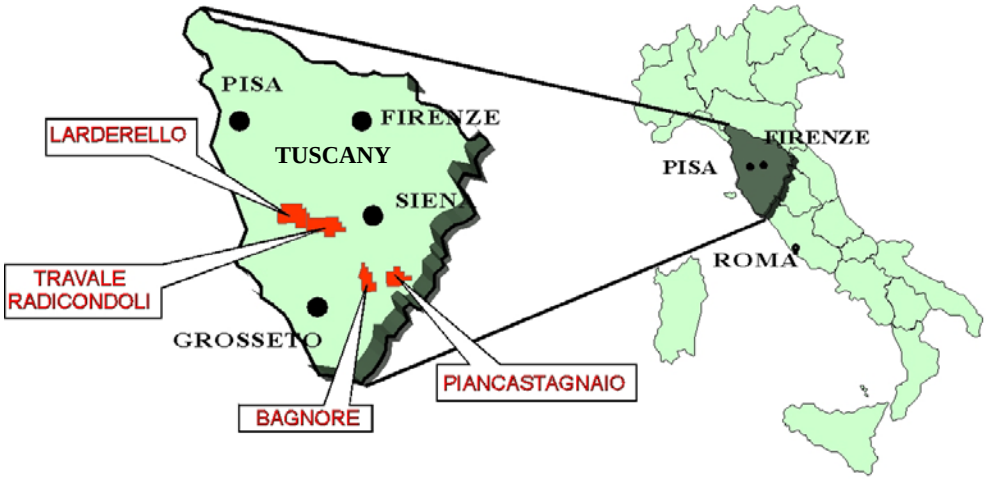

Figure 3: Location of geothermal areas in Italy

TABLE 2. UTILISATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2004

[1] N = Not operating (temporary), R = Retired. Otherwise live blank if presently operating.
[2] 1F = Single Flash D* = Steam with entrained water separated at wellhead
2F = Double Flash B = Binary (Rankine Cycle)
D = Dry Steam

Locality	Power Plant Name	Year Commissioned	No. of Units	Status[1]	Type of Unit[2]	Unit Rating MW_e	Total Installed Cap. MW_e	Annual Energy Produced 2003 GWh/yr	Total under Constr. or Planned MW_e
Larderello	Valle Secolo	1991	2		D	60	120	968	
	Farinello	1995	1		D	60	60	427.4	
	Nuova Larderello 3								20
	Nuova Gabbro	2002	1		D	20	20	144.1	
	Nuova Castelnuovo	2000	1		D	14.5	14.5	110.7	
	Nuova Serrazzano	2002	1		D	60	60	391	
	Nuova Sasso	1996	1		D	20	20	115.8	
	Le Prata	1996	1		D	20	20	139.4	
	Nuova Monterotondo	2002	1		D	10	10	57.3	
	San Martino	1985	2		D	20	40	119.2	
	Nuova San Martino				D	40			40
	Nuova Lago	2002	1		D	10	10	58.1	
	Lagoni Rossi 3	1981	1		D	8	8	45.7	
	Cornia 2	1994	1		D	20	20	108.9	
	La Leccia	1983	1	N	D	8		6.9	
	Nuova Molinetto	2002	1		D	20	20	132.8	
	Carboli 1	1998	1		D	20	20	164.2	
	Carboli 2	1997	1		D	20	20	162.7	
	Selva 1	1997	1		D	20	20	155.4	
	Monteverdi 1	1997	1		D	20	20	97	
	Monteverdi 2	1997	1		D	20	20	100	
	Sesta	2002	1		D	20	20	101.9	
SUBTOTAL			22				542.5	3606.5	60
Travale-Radicondoli									
	Nuova Radicondoli	2002	1		D	40	40	283.1	
	Pianacce	1987	1		D	20	20	123.2	
	Rancia	1986	1		D	20	20	114.1	
	Rancia 2	1988	1		D	20	20	129.7	
	Travale 3	2000	1		D	20	20	158.7	
	Travale 4	2002	1		D	40	40	299.8	
SUBTOTAL			6				160	1108.6	
Mt. Amiata									
	Bagnore 3	1998	1		1F	20	20	160.9	
	Piancastagnaio 2	1969	1		D	8	8	35.6	
	Bellavista	1987	1	R	D*	20			
	Piancastagnaio 3	1990	1		D*	20	20	155.6	
	Piancastagnaio 4	1991	1		D*	20	20	125.9	
	Piancastagnaio 5	1994	1		D*	20	20	147.3	
SUBTOTAL			6				88	625.3	
TOTAL			**34**				**790.5**	**5340.4**	**60**

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration	(all)	4				12.7
Production	>150° C	17				51.1
	150-100° C					
	<100° C					
Injection	(all)					
Total		21				63.8

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES
(Restricted to personnel with a University degree)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributied Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	20	10	15	—	—	80
2001	20	10	12	—	—	80
2002	15	10	10	—	—	78
2003	15	10	10	—	—	77
2004	15	10	10			75
Totale	85	50	57	—	—	390

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilisation		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1990-1994	104	483	5	199	99	1
1995-2000	70	498	4	154	99	1
2001-2004	24	116	16	236	97	3