GEOTHERMAL DEVELOPMENT IN ITALY: COUNTRY UPDATE REPORT

Giovanni Allegrini, Guido Cappeiii and Fabio Sabatelli

ENEL Spa DPT/VDT/G Via Andrea Pisano 120 56122 PISA

Key words: Italy, Larderello, Travale Radicondoli, Mr. Amiara

ABSTRACT

The development of geothermal activities in Italy in the five-years period 1990-1994 is described in this paper.
Elecmc installed capacity increased to 625.7 MW (January 1995) with the yearly generation reaching 3417 GWh (year 1994).
Direct uses represent a total peak capacity of 307.7 MW, with a yearly energy use of 3629.2 TJ.
The total investments in geothermal activities from 1985 to 1994 totalled 1655 million US dollars.

1. INTRODUCTION

Geothermal energy in Italy has a large potential in terms of low-temperature resources (<130°C) and a moderate one in terms of resources suitable for elecmcity generation (Cataldi and Squarci, 1978; Cataldi and Calamai, 1983).
Geothermal power production has been undergoing a slow but continuous development for many decades. In the last 5 years, the yearly geothermal power production has increased from 3150 to 3417 GWh, thus maintaining a share of the total elecmcity produced in Italy to around 1.6%. Table 1 shows the situation of geothermal power production as compared to the other sources of electricity as of Jan. 1994.
This paper updates the one presented at the previous International Symposium, by Cataldi et al. (1990).

2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRICAL GENERATION

Detailed data on installed capacity, power plans already under construction and those planned as of Dec. '94. are shown in Table 2, where the 1994 electricity generation for each unit is also reported. It can be noted that the overall capacity in the past 5 years has increased by some 81 MW in the fields of Larderello, Travale-Radicondoli and Mt. Amiata (Piancastagnaio), as a result of the construction of new power plans for a capacity of 180 MW. By taking into account the dismantling of some old units (99 MW), a total installed capacity of 625.7 MW has been reached.
ENEL's programs foresee the construction of additional units (planned within the year 2000) for a capacity of 344 MW. This value could be increased according to the results of the deep exploration programs that are in progress.

3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT USES

The present situation of direct uses of geothermal energy in Italy is shown in Tables 3 and 4. The total energy use amounts to about 3600 TJ/yr, with a peak thermal power of around 300 MW.
Compared with the previous situation, it is worth mentioning that two notable district heating systems (in the towns of Ferrara and Vicenza) started operating.
The utilization of geothermal heat pumps in Italy has been moderate up to now: very few installations of small size are in operation, above

Table 1. Present and planned production of electricity in Italy

	Geothermal		Fossil Fuels		Hydro		Nuclear		Total	
	Capacity MW_e	Gross Prod. GWh/yr (1)	Capacity MW_e	Gross Prod. GWh/yr (1)	Capacity MW_e	Gross Prod. GWh/yr (1)	Capacity MW_e	Gross Prod. GWh/yr (1)	Capacity MW_e	Gross Prod. GWh/yr (1)
In operation in January 1995.	625.7	3417	46100	180869	19950	47745	—	—	66676	232031
Under construction in January 1995	164		7300		480		—	—	7944	
Funds committed, but not yet under construction in January 1995.	180		8330		1550		—	—	10060	
Dismantling	117.2		3130				—	—	3247	
Total projected use by 2002	852.5	5200	58600	256300	21980	58300	—	—	81433	319800

(1) Production of 1994

all in the private sector. It is thus impossible to compile a complete list, and this is why Table 5 is not included in this paper.

4. RESEARCH AND DEVELOPMENT OF GEOTHERMAL RESOURCES

The localities where geothermal exploration and exploitation are currently in progress were already described in the previous updates (Ferrara et al.. 1985 and Cataldi et al., 1990), so Table 6 is omitted.
However, a map of the geothermal localities of Italy, as well as a summary of the present status of the various types of utilization, are shown in Figure 1.
Tuscany and Latium areas were the main target of surface exploration, which included both geophysical (gravimetric, seismic magnetotelluric and geoelectric) surveys and thermal gradient wells.
The results allowed a better understanding of the geothermal characteristics of these areas and helped to locate some exploratory wells in new zones.
Drilling was aimed exclusively at the research and development of high-enthalpy geothermal resources for electricity generation. This activity has been managed only by ENEL, due to AGIP's withdrawal of geothermal involvement.
Table 7 summarizes the drilling activity carried out in the period from Ian. '90 to December '94. Most of the wells have been drilled inside and at the margins of the areas already under exploitation. The goal to find fluids with better thermodynamic characteristics was realized by reaching deeper layers.
In the same period, the deep exploration programs m the areas of Monti Sabatini and Bolsena were completed.
As for the fields under exploitation, studies and field tests have been carried out for optimizing the management strategies. In the most exploited areas of Larderello field the research activities have teen mainly directed to the recovery of the energy stored in the reservoir rocks through water reinjection: very positive results have been reached in the Valle-Secolo area with a significant increase of fluid production and reservoir pressure.

5. RESOURCES AND INVESTMENTS

Since AGIP withdrew, almost all of the financial effort and resources spent for the geothermal activities have been sustained by ENEL.
The National Research Council, ENEL and a number of organizations and university institutes are involved in research activities.
For the period 1990-94, the allocation of personnel with university degrees is shown in Table 9.
As far as investments are concerned, Table 10 reports the data for the two periods 1980-84 and 1985-94.

6. CONCLUSIONS

The progress of geothermal development in Italy has teen mainly directed towards electricity generation. Direct uses have teen in fact hindered by the lack of specific financial supports.
Moreover, even the increase of the installed capacity has not fully reached the expected target outlined in the previous update (Cataldi et al., 1990) because of the growing local opposition to the installation of additional power plants. The permission process has therefore become more and more difficult and time-consuming.

REFERENCES

Cataldi R. and Calamai A., 1983. Present status and future prospects of geothermal development in Italy. Proceedings, *9rh Workshop on Geothermal Reservoir Engineering,* Stanford Univ., Stanford, CA, p. 17-29.

Cataldi R. and Squarci P., 1978. Valutazione del potenziale geotermico in Italia con particolare riguardo alla Toscana centrale e meridionale. *Proceedings, Congress A.E.I.*, Bari, Italy, Vol. 1, p. 1-8.

Cataldi, R., Ferrara G.C., Palmerini C.G. and Sabatelli F., 1990. Comparative Progress Repon 1985-89 and Projections on Future Development of Geothermal Energy in Italy. Proceedings, 1990 *International Symposium on Georhermal Energy,* Kailua-Kona, HI, Geother. Resor. Counc. Trans. 14, p. 147-159.

Ferrara G.C., Luccioli F., Palmerini G.C. and Scappini U., 1985. Update report on geothermal development in Italy. Proceedings. 1985 *International Symposium on Georhermal Energy,* Kailua-Kona, HI, International Volume, p. 95-105.

***Table* 2.** Utilization of **geothermal energy for electrical generation** in December **1994**

Locality	Power Plant Name	Year Commissioned	No of Units	Status	Type of Unit	Unit Rating MW_e	Total Installed Cap. MW_e	Annual Energy Prod. (1994) GWh/yr	Total under Constr. or Planned MW_e
Larderello	Larderello 3	1950	1 1 2	O O R	DS-C DS-C DS-C	24 26 24	98	308.3	
	Valle Secolo	1991	2	O	DS-C	60	120	913.5	
	Farinello		1	UC	DS-C	60			60
	Gabbro	1969	1	O	DS-C	15	15	127.1	
	Castelnuovo V.C.	1946	1 1	O R	DS-C DS-C	11 11	22	91.4	
	Serrazzano	1957	2 1	O O	DS-C DS-C	12.5 15	40	280.9	
	Sasso Pisano	1958	1 1	O O	DS-C DS-C	12.5 3.2	15.7	51.8	
	Nuova Sasso	1994	1	UC	DS-C	20			20
	Le Prata		1	UC	DS-C	20			20
	Monterotondo	1958	1	O	DS-C	12.5	12.5	108.4	
	San Martino	1985	2	O	DS-C	20	40	217.7	
	Lago	1960	1 1 1	O O R	DS-C DS-C DS-C	6.5 12.5 14.5	33.5	124.7	
	Lagoni Rossi 3	1981	1	O	DS-C	8	8	54.9	
	Cornia	1987	1	O	DS-C	20	20	81.1	
	Cornia 2	1994	1	O	DS-C	20	20	79.2	
	Molinetto 2	1982	1	O	DS-C	8	8	62.3	
	La Leccia	1983	1	O	DS-C	8	8	59.6	
	Carboli 1		1	P	DS-C	20			20
	Carboli 2		1	P	DS-C	20			20
	Selva 1		1	P	DS-C	20			20
	Monteverdi 1		1	P	DS-C	20			20
	Monteverdi 2		1	P	DS-C	20			20
SUBTOTAL			33				460.7	2560.9	200

Locality	Power Plant Name	Year Commissioned	No of Units	Status	Type of Unit	Unit Rating MW_e	Total installed Cap. MW_e	Annual Energy Prod. (1994) GWh/yr	Total under Constr. or Planned MW_e
Travale-Radicondoli	Radicondoli	1979	2	O	DS-C	15	30	221	
	Pianacce	1987	1	O	DS-C	20	20	104.3	
	Rancia	1986	1	O	DS-C	20	20	30.4	
	Rancia 2	1988	1	O	DS-C	20	20	109.9	
SUBTOTAL			5				90	465.6	
Mt. Amiata	Bagnore 1	1959	1	R	DS-D	3.5	3.5	0.3	
	Bagnore 2	1959	1	O	DS-D	3.5	3.5	0.4	
	Bagnore 3		1	P	DS*-C	20			20
	Piancastagnaio 2	1969	1	O	DS*-D	8	8	28.3	
	Bellavista	1987	1	O	DS*-C	20	20	137.1	
	Piancastagnaio 3	1990	1	O	DS*-C	20	20	91.7	
	Piancastagnaio 4	1991	1	O	DS*-C	20	20	133.1	
	Piancastagnaio 5	1994	1	UC	DS*-C	20			20
	Piancastagnaio 6		1	P	DS*-C	20			20
	Piancastagnaio 7		1	P	DS*-C	20			20
	Piancastagnaio 8		1	P	DS*-C	20			20
SUBTOTAL			11				75	390.9	100
Latera	Latera		2 2	UC UC	2F B	20 2			44
SUBTOTAL			4						44
TOTAL			**53**				**625.7**	**3417.4**	**344**

STATUS O=Operational
R= Reserve capacity
UC= under Construction
P= Planned

TYPE OF UNIT DS= Dry Steam
DS*= Entrained water separated at well head
C= Condensing
E= Discharging-to-atmosphere
2F= Double flash
B= Binary

Table 3. Utilization of geothermal energy for direct heat In December 1994

(1) I = Industrial process heat; D = Space heating; C = Air conditioning; B = Bathing and swimming; A = Agricultural drying; G = Greenhouses; F = Fish and other animal farming; O = Other (please specify by footnote); S = Snow melting

(2) Enthalpy information is given only if there is steam or two-phase flow

(3) Energy use (TJ/yr) = Annual average water flow rate (kg/s) x [Inlet Temp. (°C) - Outlet Temp. (°C)] x 0.1319

Locality	Type (1)	Maximum Utilization					Annual Utilization		
		Flow rate	Temperature (°C)		Enthalpy (2) (kJ/kg)		Average Flow Rate	Energy use (3)	Load Factor
		kg/s	Inlet	Outlet	Inlet	Outlet	kg/s	TJ/yr	
Piancastagnaio	G	17.50	97	50	2200	209	6.94	435.44	0.40
Larderello industr.	D	5.60	160	95	2780	398	1.89	141.87	0.34
Larderello INA	D	0.30	180	70	2755	293	0.08	6.12	0.26
Larderello villaggi	D	1.95	160	95	2780	398	0.56	41.87	0.29
Larderello SCL	I	4.30	200	80	2860	335	2.99	238.36	0.70
Castelnuovo V.C.	D	7.60	105	70	1000	293	2.25	50.24	0.30
Isolver	D	0.016	117	70	2650	293	0.005	0.37	0.31
MAF	G	1.32	105	70	1000	293	0.66	14.65	0.50
MAF	G	2.80	70	30	----	----	1.35	7.12	0.48
C.D.	G	1.10	70	60	----	----	0.33	0.44	0.30
COSVIG	F	0.30	105	70	2685	293	0.10	7.56	0.33
Lago Boracifero	G	0.70	125	100	2730	419	0.17	12.56	0.25
Bulera	G	1.00	120	40	1664	130	0.39	18.72	0.39
Euganean Hills:									
Abano Terme	B/D	580.00	78	37	—	—	200.00	1081.58	—
Montegrotto T.	B/D	470.00	75	37	—	—	170.00	852.07	—
Battaglia Terme	B/D	110.00	64	37	—	—	40.00	142.45	—
Galzignano	G	30.30	58	40	—	—	15.00	35.61	0.50
Vicenza	D	27.75	67	25	—	—	15.09	83.60	0.54
Ferrara	D	55.60	100	60	—	—	31.70	167.25	0.57
Monterotondo Mmo.	D	2.63	95	70	1000	293	0.76	16.92	0.29
Civitavecchia (Pantani)	G	238.00	52	30	—	—	58.19	168.86	0.24
Canino	G	7.80	40	35	—	—	1.96	1.29	0.25
Bagno di Romagna	D	25.00	40	18	—	—	15.02	43.59	0.60
Acqui Terme	D	9.50	70	35	—	—	5.98	27.61	0.63
Rodigo	G/F	10.57	60	18	—	—	5.97	33.07	—
Total								3629.21	

Table 4. **Summary** table **of geothermal direct heat uses**

(1) Inst. thermal power (MW_t) = Max. Water flow rate (kg/s) x [Inlet temp. (°C) - Outlet temp. (°C)] x 0.004184

(2) Energy use (TJ/yr) = Annual average water flow rate (kg/s) x [Inlet temp. (°C) - Outlet temp. (°C)] x 0.1319

	Installed Thermal Power (1) MW_t	Energy use (2) TJ/yr
Space heating	43.87	579.43
Bathing and swimming	186.65	2076.11
Agricultural drying	—	—
Greenhouses	63.79	694.69
Fish and Other animal farming	2.58	40.63
Indusrial process heat	10.86	238.36
Snow melting	—	—
Air conditionong	—	—
Other uses (specify)	—	—
Heat pumps	not available	not available
Total	307.74	3629.21

Table 7. Wells **drilled** for **electrical and combined use of** geothermal resources **from** January 1, 1990 **to December 31,1994**
(Do not include thermal gradient wells less than 100 m deep)

(1) Type or purpose of well:
T = Thermal gradient or other scientific purpose
E = Exploration
P = Production
I = Injection
C = Combined electrical and direct use
(2) Total flow rate at given wellhead pressure (WHP)
(3) Average Figures
(4) Well length (not corresponding to vertical depth in directional wells)

Locality	Year Drilled	Well Number	Type of Well (1)	Total Depth m (3) (4)	Max Temp. °C	Flowing Enthalpy kJ/kg	Well Output (2) Flow Rate kg/s	Well Output (2) WHP bar
Larderello	91	1	T	292	128	—	—	
	92-94	6	E	3828	290-363	2930	6.8	
	90-94	41	P	2848	245-420	2870	4.1	
Travale-Radicondoli	94	3	E	2479			18.0	
	90-94	11	P	3828	3W 360 -360	2800 2900	10.0	
Monte Amiata	94	1	E	3525	300		18.0	
	93-94	2	P	3595	300-360	2800	16.7	
	90-93	3	I	986				
Latera	91	3	E	3346	300-350		0.0	
	90-92	2	P	1971	220	922	166.7	
	91	1	I	2346	190			
Monti Sabatini	91-92	5	E	25881	65-300	670	81.5	
Bolsena	91-92	4	E	26381	197-2921	702	166.7	
Pantelleria	93-94	2	E	1150			1	

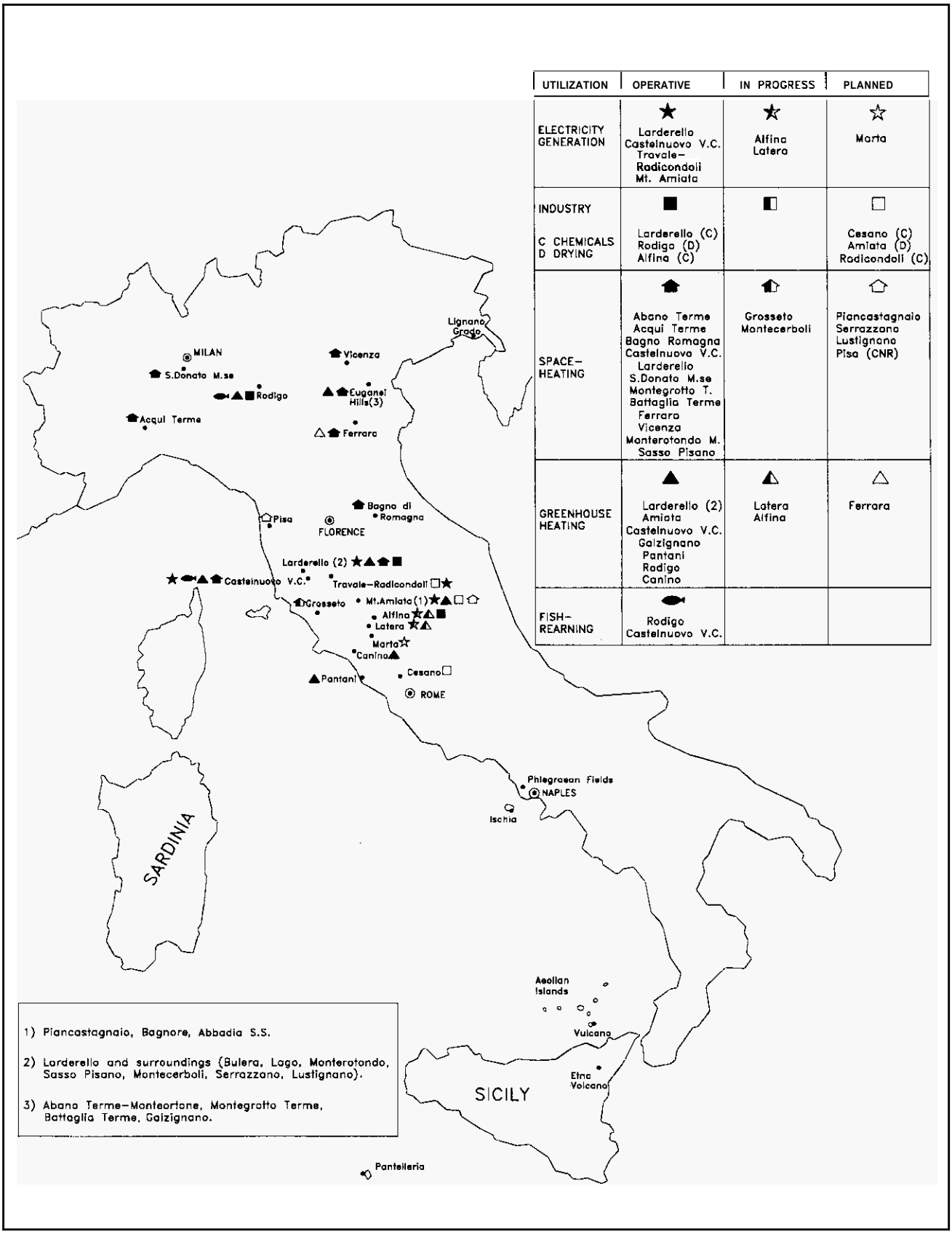

Figure 1. Main **geothermal** areas in **Italy**

Table 9. 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) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Man Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1990	45	85	25	—	—	65
1991	45	85	25	—	—	65
1992	50	15	30	—	—	145
1993	50	20	30	—	—	145
1994	50	20	30	—	—	150

Table 10. Total investments in geothermal in (1994)US$

Period	Research & Development Incl. Surf. Exp. & Exp. Drilling	Field Development Incl. prod. Drilling & Surf. Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1980 - 1984	120	154	13	41	99	1
1985 - 1994	260	930	15	450	99	1