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COMPARATIVE PROGRESS REPORT 1985-89 AND PROJECTIONS ON FUTURE DEVELOPMENT OF GEOTHERMAL ENERGY IN ITALY

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ABSTRACT

The first part of the paper summarizes the geothermal achievements in Italy in the 5-year period Jan. '85-Dec. '89 for both electrical generation and direct uses.

At the beginning of the period the situation was as follows: installed capacity 459 MW, with a production of 2840 GWh/yr (1.6% of the total electricity generated in Italy in 1984); direct applications for a total saving of 190,000 OET/yr, of which 124,000 was accounted for by balneology only and the rest by all other direct uses.

The situation as of Dec. '89 was as follows: installed capacity 545 MW, with a production of 3150 GWh/yr (1.5% of total electrical generation in Italy in 1989); direct uses for a total saving of about 200,000 OET/yr, of which some 127,000 for balneology and a bit more than 70,000 OET/yr referring aggregately to agribusiness, industry and other minor direct applications.

The second part of the paper is mainly focused on geothermal power development to the year 1995. It deals with strategy, objectives, resources, investments and expected results.

Installed capacity is planned to increase significantly in the next few years, rising to 885 MW by Dec. '95, with production reaching approximately 4700 GWh in that year.

Direct uses, on the contrary, are expected to increase slowly in the period 1990-95: overall growth is unlikely to exceed 215,000 OET in 1995, of which approximately 130,000 for balneology and some 85,000 for space heating, agribusiness and industry. The latter figure is less than half that foreseen some 10 years ago for geo-heat projects other than balneology.

INTRODUCTION

Among the conventional sources of primary energy, only hydropower has significant potential in Italy. This potential, however, is far from sufficient to meet the Italian electricity demand. On the other hand, among the nonconventional sources of energy, geothermal heat has a huge potential in terms of low-temperature resources (<130°C), but a rather limited one in terms of resources suitable for electrical generation (Cataldi and Squarci, 1978; Cataldi and Calamai, 1983).

Nonetheless, geothermal power production has undergone slow but continuous development in Italy for many decades. Limited to the last 10 years, it can be said that the geothermal share of the total electricity produced in Italy has always remained at values of 1.5-1.6%. These values may seem modest in percentage terms, but are very significant when one considers that total power production in Italy has gradually risen from the 174,000 GWh of 1980 to the 200,000 GWh of 1989. Table 1 shows the situation of geothermal power production as compared to the other sources of electricity as of Jan. 1990.

The overall geothermal achievements in Italy have frequently been reported to the international community. Among the many papers dealing with this general subject during the 1980s, the comprehensive progress reports by Cataldi and Calamai (1983), Palmerini et al. (1984), Ferrara et al. (1985), Baldi and Cataldi (1986) should be cited. This paper is particularly closely related to that of Ferrara et al. (1985) and is divided into two main parts. The first describes the activities and results of the five-year period 1985-89; the second summarizes the goals and the development program up to 1995.

With regard to the first part of the paper, in order to facilitate comparison between the situations as of Jan. '85 and Dec. '89, in addition to the standard Tables 1 through 6, reference should be made to the progress report by Ferrara et al. (1985). Moreover, three extra tables, labeled with Roman numerals, have been introduced for easier comparison of summary data.

PART I: ACHIEVEMENTS IN THE 5-YEAR PERIOD JAN. '85-DEC. '89

ACTIVITIES DIRECTED AT GEOTHERMOELECTRIC PRODUCTION

Research and surface exploration. Research on fundamental aspects of geothermal energy is a permanent activity of the Italian geothermal program. It is conducted by several organizations: the National Research Council of Italy through its International Institute for Geothermal Research and the Subproject Geothermal Energy of the Finalized Energy Project, a number

TABLE 1 - PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

		Geothermal		Fossil Fuels		Hydroelectric		Nuclear	
		Capacity MW.	Utilization GWh/yr	Capacity MW.	Utilization GWh/yr	Capacity MW.	Utilization GWh/yr	Capacity MW.	Utilization GWh/yr
In operation	Jan. 1990	544.7	3150	39450	162880	18420	37190	1152	0
Under construction	Jan. 1990	160	-	13150	-	2150	-	0	0
Funds committed, but not yet under construction	Jan. 1990	386	-	6700	-	-	-	0	0
Total projected use	by 1995	885[1]	4700	52600	178000	20570	48000	1152	0

[1]After dismantling of 205.7 MW.

of university institutes, ENEL, AGIP and others. In the period in question, even though practically all fundamental aspects of geothermal research have been reviewed and revised, the following activities are worthy of specific mention: updating of temperature distribution within 3 km depth, thickening of heat flow density map (both land and seabottom), reconstruction of deep geologic structures, investigations on igneous processes and formation of regional thermal anomalies, chemistry of underground fluids, reservoir modeling and production performance, research on scaling processes, investigations on thermal breakthrough due to reinjection, tests on modulated production of steam reservoirs.

Surface exploration includes detailed geological, hydro-geochemical and geophysical surveys and prospecting of various kinds carried out in practically all high-temperature areas of Italy, and in particular in the areas of Larderello, Travale-Radicondoli, Orciatico, Roccastrada, Mt. Amiata, Volsini Mtns., Cimini Mtns., Alban Hills, Naples and surroundings, Aeolian archipelago and SW Sardinia (Fig. 1 and Table 3). Of course, these surveys and prospectings were assigned differing objectives depending on the advancement of the work program in each area. In the case of old exploited fields, the objectives were to improve knowledge of the geothermal system (permeability distribution in the reservoir, structural attitude, water-rock interaction, hydrogeological balance, etc.), to infer the existence of producing layers at 3-5 km depth, and to investigate the geological structure outside the boundaries of the presently producing areas. On the contrary, in the new areas the main objective was to locate the most favorable sites to start exploration drilling.

Drilling. This activity has been conducted prevalently by ENEL in Tuscany and Latium and, to a lesser extent, by AGIP (on behalf of the ENEL-AGIP joint venture) in a few areas of Latium, Campania and Sicily.

Drilling carried out in the 5-year period under review is shown in Table 4, whereas comparative figures of the situations as of Jan. '85 and Dec. '89 are summarized in Table I. From the latter table can be noted: i) the distribution of the total metrage among the various areas; ii) the increase of drilling activity in the more promising areas; and iii) the significant increase in average well depth in the areas of Larderello, Travale-Radicondoli and Mt. Amiata.

As regards the latter aspect (see comparative figures in Tables 4 and I), attention should be drawn to the fact that in the last few years directional drilling has resulted in an apparent increase of the average well depth in the area concerned. At Larderello, Travale-Radicondoli and Mt. Amiata, however, the increase in average well depth is largely real and is attributable to exploration of deep layers located more than 2.5 km below ground level.

Finally, it is worth mentioning that, despite the general increase of the average well depth in the abovesaid old producing fields, the drilling success ratio has remained around 65%, mainly due to the results in the Piancastagnaio field. At Larderello, though, lower permeability conditions were found to exist within the metamorphic complex, as compared to those of the overlying

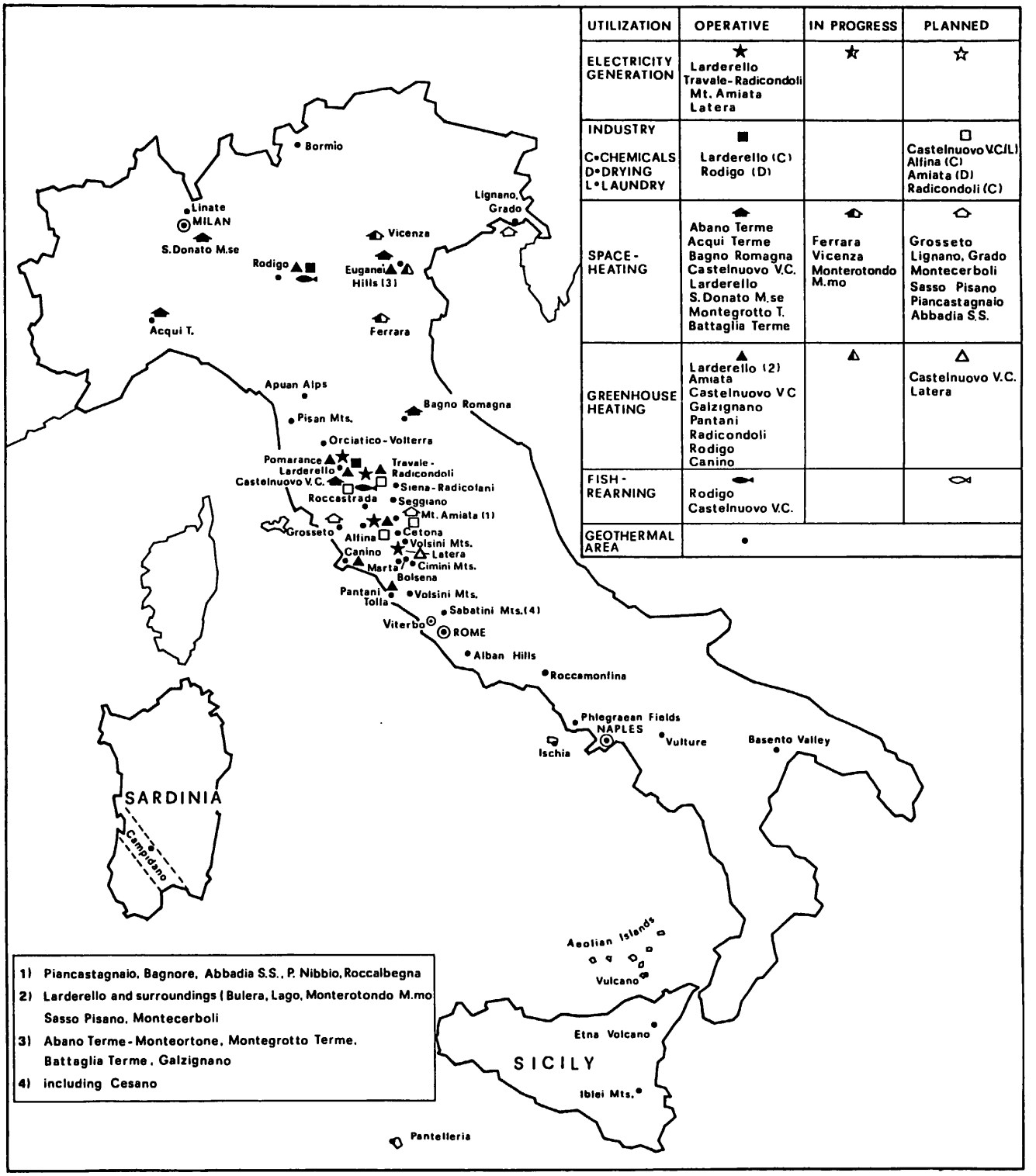

Figure 1. Main geothermal areas in Italy.

TABLE 2A - UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRICAL GENERATION IN DECEMBER 1989

Locality	Power plant name	Year	No. of units	Status	Type of unit	Unit rating (MW_e)	Total installed capacity Dec. 89	Total under const. or planned
Larderello	Larderello 2	1946	4*	Operational	DS	14.5	58	-
	Larderello 3	1950	3* 1* 1	Operational Operational Dismantled	DS DS DS	24 26 9	98	-
	Valle Secolo	-	2	Under const.	DS	60	-	120
	Larderello Nuova	-	2	Planned	DS	60	-	120
	Farinello	-	1	Planned	DS	60	-	60
	Gabbro	1969	1	Operational	DS	15	15	-
	Castelnuovo V.C.	1946 -	2 1* 1 1	Operational Operational Dismantled Planned	DS DS DS B	11 26 2 1	48 -	- 1
	Serrazzano	1957	2 1* 1 1	Operational Operational Dismantled Operational	DS DS DS DS	12.5 3.5 3.5 15	43.5	-
	Sasso Pisano	1958	1* 1* 1	Operational Operational Dismantled	DS DS DS**	12.5 3.2 3.5	15.7	-
	Sasso Pisano 3	-	1	Planned	DS	20	-	20
	Monterotondo	1958	1	Operational	DS	12.5	12.5	-
	San Martino	1980 1985 1988	1 1 1	Dismantled Operational Operational	DS DS DS	9 20 20	40	-
	Lago	1960	1 1 1	Operational Operational Operational	DS DS DS	6.5 12.5 14.5	33.5	-
	Lagoni Rossi 1	1961	1	Dismantled	DS**	3.5	-	-
	Lagoni Rossi 3	1981	1	Operational	DS	8	8	-
	Cornia	1987	1	Operational	DS	20	20	-
	Cornia 2	-	1	Planned	DS	20	-	20
	La Leccia	1983	1	Operational	DS	8	8	-
	Molinetto 2	1982	1	Operational	DS	8	8	-
	Carboli 1	-	1	Planned	DS	20	-	20
	Selva 1	-	1	Planned	DS	20	-	20
	Monteverdi 1	-	1	Planned	DS	20	-	20
	Monteverdi 2	-	1	Planned	DS	20	-	20
SUBTOTAL			28[1]				408.2[2]	421

Table 2A (cont.)

Travale-Radicondoli	Travale 2	1976	1 1	Dismantled Dismantled	DS**	15 3	-	-
	Radicondoli	1979	2	Operational	DS	15	30	-
	Pianacce	1987	1	Operational	DS[3]	20	20	-
	Rancia	1986	1	Operational	DS[3]	20	20	-
	Rancia 2	1988	1	Operational	DS[3]	20	20	-
	Travale 21	-	1	Under const.	B	1	-	1
SUBTOTAL			5[1]				90	1
Mt. Amiata	Bagnore 1	1959	1	Operational	DS**	3.5	3.5	-
	Bagnore 2	1962	1	Operational	DS**	3.5	3.5	-
	Piancastagnaio 2	1969	1	Operational	DS[3]**	15	15	-
	Bellavista	1987	1	Operational	DS[3]	20	20	-
	Piancastagnaio 3	-	1	Under const.	DS[3]	20	-	20
	Piancastagnaio 4	-	1	Under const.	DS[3]	20	-	20
	Piancastagnaio 5	-	1	Planned	DS[3]	20	-	20
	Piancastagnaio 6	-	1	Planned	DS[3]	20	-	20
SUBTOTAL			4[1]				42	80
Latera	Latera	1984 - -	1* 2 4	Operational Planned Planned	1F** 2F B	4.5 20 1	4.5 - -	- 40 4
SUBTOTAL			1[1]				4.5[4]	44
GRAND TOTAL			38[1]				544.7[5]	546

*Units to be dismantled by 1995; **Discharging-to-atmosphere units.

[1]Operational; [2]201.2 MW to be dismantled by 1995; [3]Entrained water separated at wellhead; [4]4.5 MW to be dismantled by 1995; [5]205.7 MW to be dismantled by 1995.

DS = dry steam; C = condensing unit; 1F = single flash; 2F = double flash; B = binary.

TABLE 2B - UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT[1] - DECEMBER 1989

Locality	Type*	Maximum Utilization					Average Annual Utilization				
		Flow Rate kg/s	Temperature °C		Enthalpy kJ/kg		Flow Rate kg/s	Temperature °C		Enthalpy kJ/kg	
			Inlet	Outlet	Inlet	Outlet		Inlet	Outlet	Inlet	Outlet
Mt. Amiata[a]	G,A	30	97	50	2200	209	14	97	55	2200	230
Piancastagnaio[b]	F	13.5	120	85	-	-	1.4	92	83	-	-
Larderello	D	1.3	160	95	2780	398	0.45	160	95	2780	398
	D	0.3	180	70	2755	293	0.08	180	70	2755	293
	I	4.3	200	80	2860	335	3.0	200	80	2860	335
Castelnuovo	G	0.4	70	60	-	-	0.15	70	60	-	-
Val di Cecina	G	1	105	75	1000	314	0.3	95	80	1000	335
	D	7.6	105	70	1000	293	2	105	75	1000	314
	F	0.36	105	70	2685	293	0.1	105	75	2685	314
	I	0.02	117	70	2650	293	0.01	117	70	2650	293
Lago	G	0.7	125	100	2730	419	0.3	125	100	2730	419
Bulera[c]	G	1[d]	120	40	1664	130	0.4[d]	120	55	1664	190
Radicondoli	G	12.8	120	65	950	272	4.5	120	70	950	293
Euganean Hills:											
Abano Terme	B,D	580	78	37	-	-	200	78	37	-	-
Montegrotto T.	B,D	470	75	37	-	-	170	75	37	-	-
Battaglia T.	B,D	110	64	37	-	-	40	64	37	-	-
Galzignano	G	30	58	35	-	-	15	58	40	-	-
Vicenza[e]	D	33.3	65	30	-	-	18	65	40	-	-
S. Donato M.se	D	13.9	62	25	-	-	4.1	62	35	-	-
Ferrara[e]	D	111	95	35	-	-	35	95	45	-	-
Monterotondo M[b]	D	17.2	95	70	-	-	6.4	95	75	-	-
Pantani	G	68	48	30	-	-	17	48	30	-	-
Canino	G	8	40	35	-	-	2	40	35	-	-
Bagno Romagna	D	25	40	18	-	-	15	40	18	-	-
Acqui Terme	D	9.3	70	35	-	-	6	70	35	-	-
Rodigo	G,D,F	11	60	18	-	-	6	60	18	-	-

[1]Excluding balneology.

*Type of use: I = Industrial process heat; D = District heating; B = Bathing and swimming; A = Agricultural drying; G = Greenhouses; F = Fish and other animal farming.

[a]The agricultural drying plants are still to be built. The data given refer to the whole exploitation system, including drying plants.
[b]Under construction.
[c]Given data also include electric generation (50 kW_e by means of a binary plant), still to be installed.
[d]The fluid is a mixture of steam and CO_2.
[e]In operation by the end of 1990.

TABLE 3 - INFORMATION ABOUT GEOTHERMAL LOCALITIES*

Locality	Location To Nearest 0.5°		Reservoir		Status[3] in January 1990	Reservoir Temp. °C	
	Lat.	Long.	Rock[1]	Water[2]		Estimated	Measured
Orciatico-Volterra	43°26'	10°44'	Limestone and metamorphic rocks	2000-8000	P	200-250	-
Roccastrada	43°07'	12°14'	Metamorphic rocks	2000-8000	R	200-250	-
Seggiano	42°56'	11°29'	Metamorphic rocks	2000-8000	P	200-250	-
Roccalbegna	42°43'	11°26'	Metamorphic rocks	2000-8000	R	200-250	-
Tolfa	42°09'	11°57'	Limestone	3000-5000	R	200-250	-

*Only new areas are reported; for the others see Ferrara et al. (1985).
[1]Main type of reservoir rock.
[2]Total dissolved solids, in mg/kg, before flashing.
[3]R = Regional assessment; P = Pre-feasibility studies.

TABLE 4 - WELLS DRILLED FOR ELECTRICAL UTILIZATION OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1985 TO JANUARY 1, 1990

Locality	Year Drilled	Well Number	Type of* Well	Total Depth[1,2] (meters)	Max. Temp. °C	Flowing Enthalpy[1] kJ/kg	Flow Rate[1] kg/s
Larderello	1986	5	T	150	25-30	-	-
	1985-1989	4	E	3299	310-341	3000	10.4
	1985-1989	19	P	2533	205-354	2900	8.0
	1986	2	I	602	-	-	-
Travale-Radicondoli	1985	1	E	2501	300	2800	2.0
	1989	1	P	2948	174	-	-
Bagnore (Mt. Amiata)	1987-1989	4	E	3141	269-310	2500	21.5
Piancastagnaio (Mt. Amiata)	1985-1987	18	P	3230	302-344	2600	22.9
	1989	1	I	1025	-	-	-
Seggiano	1988	5	T	241	26-39	-	-
Latera	1985-1986	1	T	241	17	-	-
	1988-1989	2	E	2379	420	-	-
	1985	2	P	2449	189-213	800	83.3
	1985	2	I	955	128-168	-	-
Torre Alfina	1987	1	T	268	30	-	-
	1988	1	E	4826	206	-	-
Bolsena	1985-1988	4	E	2969	188-280	800	27.8
Sabatini Mtns.	1989	2	T	259	18-34	-	-
	1985	1	E	2348	191	-	-
Cimini Mtns.	1984	4	T	187	25-33	-	-
	1989	2	E	1790	110	-	-
Vulcano	1987	1	E	975	135	-	-
Other areas	1985-1989	6	T	376	23-70	-	-

*T = Thermal gradient or other scientific purpose; P = Production; E = Exploration; I = Injection
[1]Average figures.
[2]Well length (not corresponding to vertical depth in directional wells).

TABLE I - DRILLING IN THE PERIOD JANUARY 1985 - DECEMBER 1989 AND PLANNED FOR THE PERIOD 1990-1995
(thermal gradient wells excluded)

Zone	Sit. Jan. 1985		Jan.'85-Dec. '89		Sit. Jan. 1990		Jan. '90-Dec. '95	
	Wells drilled (No.)	Average depth (m)	Wells drilled (No.)	Total metrage (m)	Wells drilled (No.)	Average depth (m)	Wells to be drilled (No.)	Total metrage (m)
Larderello	578	735	34[2]	89313	603	819	43	144000
Travale-Radicondoli	59	1165	2	8457	61	1216	6	21000
Mt. Amiata	72	1115	23	74529	95	1600	13	44500
Latera, Bolsena	11	2130	10	21318	21	2232	11	29000
Cesano, Sabatini	12	2520	1	2348	13	2507	4	10000
Torre Alfina	9	1200	1	4826	10	1563	-	-
Phlegraean Fields	12	2380	-	-	12	2380	-	-
Other zones	25	1420	3	5336	28	1431	2	7000
Totals	776		74	206127	850		79	255500

[1]Meters actually drilled in the period, including directional drilling. Work-over and plugging are excluded.
[2]Including 9 deepenings.

carbonate formations that constitute the main reservoir.

Field management. It can be seen in Table 4 that the temperature of exploration and production drillings, as well as the enthalpy of produced fluids, are significantly high in all explored areas. The average flow rate of the wells, on the contrary, is relatively high in water-dominated fields, whereas it is only a few tens of tons/h in most of the steam-producing areas. The low specific productivity of the steam wells is clearly the result of two combined effects: deficit in mass balance in the reservoir, and frictional pressure losses that the steam undergoes while moving through fractures and other geological discontinuities.

Field management in steam-dominated areas has consequently been focused in the last few years on reducing as much as possible the pressure losses due to the migration of steam between high- and low-pressure sectors of the reservoir. This has been achieved by drilling deeper and/or directional wells and, in some cases, also by applying stimulation techniques aimed at increasing the local permeability of the producing layers. However, stimulation operations have also been conducted in some wells in the water-dominated fields.

Another important activity in the sector of field management in the past 5-year period is the systematic reinjection of condensed steam to partially reduce the deficit in mass balance and the pressure decline. Reinjection for this purpose has concerned, in particular, the most intensively exploited areas of the Larderello field.

In some of the water-dominated fields, tests have been continued on scaling prevention by means of controlled injection of inhibiting chemicals. Results in this sector of activity are becoming more and more satisfactory, but further tests are still needed.

Finally, it should be mentioned that monitoring of microseismic activity has been extended to practically all working areas. The monitoring systems of all the areas in Tuscany and Latium are being interconnected with the main control station located in Larderello, which enables the recording all microseismic events including those related to exploitation, reinjection and stimulation operations.

Electrical generation. Detailed data on installed capacity and power plants under construction as of Dec. '89 are provided in Table 2A, while comparative summary figures for '85-'89 are shown in Table II. From the latter table it can be noted that the overall capacity in the past 5 years has increased by some 85 MW, mostly because of the new power units installed at Travale-Radicondoli and Mt. Amiata (Piancastagnaio). In the Larderello area, though, several old units have been dismantled and replaced by new ones (see

TABLE II - GEOTHERMAL POWER PLANTS IN ITALY

Area	Situation Jan. 1985		Situation Jan. 1990		Projected sit. 1995	
	No. of Units	Installed Capacity (MW)	No. of Units	Installed Capacity (MW)	No. of Units	Installed Capacity (MW)
Larderello	31	384.7	28	408.2	28	628
Travale-Radicondoli	4	48	5	90	6	91
Mt. Amiata	3	22	4	42	8	122
Latera	1	4.5	1	4.5	6	44
Totals	39	459.2	38	544.7	48	885

TABLE III - SUMMARY OF DIRECT USES OF GEOTHERMAL ENERGY IN ITALY

Use	Situation Jan. 1985		Situation Jan. 1990		Projected sit. 1995	
	Capacity (MW_t)	OET/yr ($x10^3$)	Capacity (MW_t)	OET/yr ($x10^3$)	Capacity (MW_t)	OET/yr ($x10^3$)
Balneology/ Balneotherapy	375	124	382	127	390	130
Space heating	110	35	117	37	125	40
Agribusiness (greenhouses, drying, etc.)	55	17	61	19	65	25
Industry	25	14	30	17	35	20
Total	565	190	590	200	630	215

Table 2A). This dismantling and replacement is part of a large modernization program (called "Larderello Renewal Project") that was started in the past 5-year period and which will be completed in the next few years (see details in last column of Table II and in Part II).

MAIN DIRECT HEAT UTILIZATION PROJECTS

For general information concerning direct heat utilization, reference should be made to the paper by Ferrara et al. (1985). Below and in Table 2B an update is given of the main geo-heat projects only. However, Table III summarizes the present overall situation and compares it to that in 1985. Where drilling for direct heat projects is concerned, we are unable at present to provide the data required by Table 5, because the national inventory of low-temperature resources and wells is still under way.

San Donato Milanese. The district heating project previously planned has become operational. The volume of the buildings heated is 385,000 m^3 (the geo-heat contribution is 40% of the peak load).

Vicenza. This district heating project will be completed within 1990. The use of electrically driven heat pumps (and conventional boilers during peak load) to increase the water temperature for the heating of 1,102,000 m^3 of buildings is envisaged. Moreover, sanitary hot water will be produced and distributed.

Ferrara. A district heating project is now almost completed and is expected to go into operation during 1990, heating buildings totaling 2,600,000 m^3. The geo-heat contribution will be about 50% of the peak load and the integrative heat will be supplied by conventional boilers.

Larderello region and Travale-Radicondoli. Larderello: additional buildings (INA-Casa), for a total volume of 23,700 m^3, are now heated by a heat exchanger system supplied by low-pressure steam. Moreover, industrial utilization of the

same kind of steam in a chemical plant for the production of boric acid from imported boron minerals is operational.
Castelnuovo V.C.: district heating (210,000 m^3) and greenhouses (5200 m^2) have become operational. Low-pressure steam is used to produce hot water feeding the distribution network.
Bulera: this project, using a low-quality steam (50% by weight noncondensable gas), has been partially implemented. The greenhouses are operational, but the planned 50 kWe binary generator is not yet in operation.
Radicondoli: the installation of a binary 1 MW unit is in progress; the cascading heat feeds the greenhouses (24,000 m^2 for the production of ornamental plants and flowers), which have already been completed.
Monterotondo Marittimo: a district heating system for this village using low-pressure steam is under construction.

Mt. Amiata. In addition to the existing greenhouses, heating of a turkey breeding farm is currently under construction. The steam is supplied by the network feeding the existing Piancastagnaio power plant.

Other areas. A number of other projects, mainly district heating and greenhouses, have become operational in various parts of Italy. Among the most important ones, the projects of Rodigo (greenhouses, agricultural drying and fish rearing), Acqui Terme and Bagno di Romagna (district heating), Pantani and Canino (greenhouses) are worthy of mention.

PART II: PLANNED DEVELOPMENT TO THE YEAR 1995

Although the Italian law No. 896/86 (the so-called "Geothermal Law") does not rule out but rather encourages the activity of geothermal operators other than ENEL both as field developers and as small producers, there is good reason to believe that in the next few years as well the chief role in geothermal development in Italy will be played by ENEL, at least with regard to power generation.

In relation to direct applications, however, the game remains open to all those (whether public organizations or private entrepreneurs) who might have an interest in developing utilization projects for low-temperature geothermal heat. ENEL's role, by contrast, is that of public adviser to prospective users and, in some cases, that of supplier of fluid not usable for producing electric power. Unfortunately, in recent years the economic advantageousness of utilizing natural heat for energy uses has been in decline, and the low-temperature projects have marked time or even been canceled. The most significant example in this regard is that of Cesano. In the coming years, therefore, it is foreseeable that Italian geothermal development will be predominantly based on the exploitation of fluids at high enough temperatures to allow their utilization for the production of electricity. For this reason the second part of this paper is mainly focused on geothermal power production.

STRATEGY

The general lines along which Italy's geothermal program will be implemented in the next few years are as follows:
- continuation of R&D activity on any fundamental aspects related to geothermal development, such as investigation methodologies, prospecting techniques, resource assessment, drilling technologies, stimulation techniques, scaling prevention, instrumentation, corrosion control, optimization of fluid gathering, power plant technologies, reinjection of spent fluid, techniques to reduce environmental impact, etc.;
- continuation of surface prospecting and pre-feasibility studies on any new areas of potential interest for finding high-temperature fluids;
- completion of feasibility studies in the most promising areas;
- exploitation of old producing areas to the maximum extent possible in relation to available resources and reservoir performance;
- continuation of deep drilling (3-5 km depth) in some areas of the Larderello/ Travale and Bagnore/Piancastagnaio fields;
- development of new areas suitable for electricity production;
- reinjection of spent water and condensed steam;
- artificial recharge, whenever possible, of steam-producing areas;
- reduction to the greatest possible extent of the time lapse between fluid discovery and fluid utilization;
- replacement or modernization of old power plants and installation of new units. Two standardized sizes will be used for the new units: 20 and 60 MW;
- relocation of the old "generation poles", accompanied by modernization and more efficient network distribution of the related gathering systems;
- assessment of market demand for low-temperature heat, aimed at identifying all large prospective users of natural heat;
- stimulation of demand by incentives to geo-heat projects other than balneology;
- completion of the national inventory of geothermal resources, as the reference base for long-term plans for geothermal development.

PROJECT AREAS AND MAIN ACTIVITIES

In general, the areas where the geothermal activities will be mostly concentrated in the coming years are those that have been under exploitation for many or several decades, and others which are in the early exploration stage. In particular, for each of them the activity and expected results can be summarized as follows.

Larderello and surrounding areas. Activities include work-over and deepening of old wells, drilling of deep wells (3-5 km) in the central, most exploited part of the field, exploratory drilling near the borders of the known production

area, injection of condensed steam to partially recharge the reservoir, replacement of old plants with new 20 and 60 MW units (Allegrini et al., 1985), rearrangement and modernization of the pipeline network, modernization and remote control of all generating units. As concerns the 60 MW units (five are to be installed within the next few years), they will be operated under load modulation conditions to obtain peak production of electricity. Drilling in this area in the period 1990-95 involves 43 wells, for a total of 144 km.

The objectives of this activity are: i) to reduce as much as possible the flow rate and pressure depletion of the old areas; ii) to increase production from deep layers and/or peripheral areas; iii) to improve power plant efficiency; and iv) to attain a stabilized production of the field at the maximum level compatible with the prolongation of the commercial life of the reservoir for at least another 25 years. The installed capacity in this area by the end of 1995 is shown in Table II, and the expected production in the same year is on the order of 3300 GWh.

As concerns direct uses, other projects, in addition to the existing ones, are planned: production of *algae spirulina* and washing/drying of goose down in Castelnuovo V.C.; district heating of the villages of Montecerboli and Sasso Pisano.

Travale-Radicondoli. Surface prospecting and exploratory drilling is planned on the outskirts of the presently producing area, as well as a number of makeup wells to maintain production. Moreover, a 40-km-long water pipeline will be completed, enabling transportation of spent water and condensed steam from this area to that of Larderello, with the aim of increased recharge of the Larderello reservoir.

Geothermal heat utilization for the production of jellies and pharmaceutical gels is planned, together with CO_2 production from gas discharged by the existing power plants.

Mt. Amiata region. Drilling and exploitation activities in this area will be mostly concentrated in the Piancastagnaio field and subordinately in the Bagnore field and other zones (Poggio Nibbio, Roccalbegna and Seggiano). The goal at Piancastagnaio is maximum exploitation of the 3-4 km deep producing layers (i.e. the water-dominated part of the reservoir) and additional installation in the next few years of some 80 MW.

At Bagnore, too, deep drilling will be continued to exploit the deep layers (3-4 km) that have been found below the presently exploited shallow reservoir. Moreover, construction activity aimed at installing new power units will be begun towards the end of 1995.

As regards direct uses, district heating is planned for the main towns in the area, starting with those located in the SE sector of the Amiata region (Piancastagnaio, Abbadia S.S.).

Latera and surrounding areas. Drilling will be continued in the water-dominated Latera field with two objectives in mind: to exploit the presently known reservoir and to explore the outskirts of the field. Among the surrounding areas (Alfina, Marta, etc.), particularly promising seems to be that of Marta.

Reservoir studies carried out so far and well testing now under way indicate that the planned capacity (two 20 MW condensing units by 1993) represents a minimum potential of the Latera field and the surrounding areas. Thus, it is possible that plans and objectives will be expanded in the coming years.

As the electrical utilization will feature a double-flash scheme, use of the residual water to heat greenhouses is planned and a district heating feasibility study will be carried out. Moreover, one of the wells in the Alfina area will be commercially exploited to produce CO_2.

Other high-temperature areas in Tuscany and Latium. These areas include, from north to south: Monticiano-Roccastrada, Orciatico, eastern Volsini Mtns., Sabatini Mtns., and the Alban Hills. In all these areas, surface prospecting will be refined and exploratory drilling will be started or continued in the next few years, but no installation of generating plants is envisaged at present.

As regards Cesano (see Fig. 1), the implementation of a multipurpose project aimed at generating electricity, commercializing valuable chemicals associated with the hot brine and at supplying heat for district heating, has proved to be unfeasible for the moment. However, plans for this project might be partly resumed within the next few years.

Phlegraean Fields and surrounding areas. Considerable efforts have been made in this region to characterize the reservoir and assess its overall geothermal potential. However, the notable difficulties encountered in managing the field during the exploration stage (due to both reservoir and fluid characteristics), accompanied by severe environmental constraints of various kinds (the central part of the Phlegraean Fields is now totally covered with houses and other buildings), have resulted in the shelving, for the moment, of the previous plans to install a power plant in this area. Therefore, the plans to develop geothermal energy in the region around Naples are to be revised, in order to establish whether a different project approach can be followed to tap the huge but difficult to manage potential of the area.

Aeolian archipelago. Having ascertained that the reservoir on the island of Vulcano is characterized by very high temperature and low permeability, the project on this island might be

TABLE 6 - ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES
(Restricted to Personnel with a University Degree)

Year	(Professional Man-Years of Effort)					
	(1)	(2)	(3)	(4)	(5)	(6)
1985	40	75	20	-	-	60
1986	40	75	20	-	-	60
1987	45	80	25	-	-	65
1988	45	80	25	-	-	65
1989	45	85	25	-	-	65
1995	50	100	30	-	-	70

(1) Government; (2) Public utilities; (3) Universities; (4) Paid foreign consultants; (5) Contributed through foreign aid programs; (6) Private industry.

reconsidered according to the HDR approach. While it cannot be ruled out that the Vulcano project will be resumed in the near future, it is more likely that in the next few years attention will be shifted towards the nearby island of Lipari, where a feasibility study (exploration drilling, well testing, etc.) may be started.

Intermediate-to-low temperature areas. The district heating projects for the towns of Vicenza and Ferrara (see Part I) will be completed and become fully operational in the very near future. Moreover, the following district heating projects are likely to be started: Grado, Lignano and Grosseto (see Fig. 1).

Other new areas in central-western Italy, Sicily and Sardinia might be developed in the next few years for the production of intermediate- or low-temperature water only, if the market demand for heat undergoes a sizable increase, or in the case that utilization of natural heat is stimulated by adequate incentives.

RESOURCES AND INVESTMENTS

It is clear from the above that most of the activities planned for the period 1990-95 refer to projects focused on geothermal power production in Tuscany and Latium. Thus, almost all of the financial effort and resources needed for developing the Italian geothermal program will be borne by ENEL.

Another organization involved on the industrial level is AGIP (ENI group), which is the main operator, on behalf of the ENEL-AGIP joint venture, for the areas of Bolsena, Viterbo, Phlegraean Fields and the Aeolian archipelago. In addition, AGIP is sole field operator for the San Donato Milanese low-temperature project.

On the scientific level, though, besides the National Research Council, ENEL and AGIP, a number of organizations and university institutes are involved.

As regards human resources, it can be estimated that some 1700 people (excluding those involved in plant manufacturing) are currently engaged full-time in Italy for geothermal activities, over 90% of which work for ENEL. The allocation of personnel with university degrees for the years 1985-89 is shown in Table 6. The same table is expanded to show the expected increase by 1995.

Where investments are concerned, those of ENEL only are quoted below, as yearly averages, for the period 1990-95:

- Research and surface exploration: 15 x 10^9 LIT/yr
- Deep drilling (excluding thermal gradient holes): 75 x 10^9 LIT/yr
- Construction of power plants (including manufacturing, civil engineering, assembly, etc.): 120 x 10^9 LIT/yr
- Other costs (operation and maintenance, general, etc.): 50 x 10^9 LIT/yr

for a total of 260 x 10^9 LIT/yr (≈200 x 10^6 U.S. $) at the exchange rate as of March 1990 of approx. 1250 LIT/$).

CONCLUSIONS

As can be seen from the above, Italy's geothermal development within the next few years is extremely clear as far as electric power production is concerned, but rather uncertain with regard to direct uses.

The 1990-95 program regarding geothermal power generation makes up only one part of a wider ranging twelve-year program that ENEL has recently launched, called "Project 2000". This project presents two possible development scenarios, and hence two different production goals for the year 2000: a reasonably sure one of 6-6.5 TWh/yr, and another of approximately 9 TWh/yr. It is too

early to say whether this second, more ambitious objective can be achieved in the next 10 years or not. Achieving it in fact depends on a series of factors, the main ones being: i) the geological availability of the resource for a utilization period of at least 25 years; ii) the cost of the substitute energy sources; and iii) a series of operating constraints, such as the obtaining permits for drilling, reinjection and power plant construction, and other obligations related to environmental compatibility.

In any case, even considering the minimum goal mentioned above, and independently of the greater effort that might be needed to speed up development of the direct applications, Italy's geothermal program for the next decade is a very demanding one, from both the organizational and financial points of view. To cite just one figure, it is sufficient to point out here that ENEL's overall commitment for the aforementioned "Project 2000" is 3100 billion Italian liras at present costs.

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