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NON-ELECTRIC USES OF GEOTHERMAL ENERGY IN ITALY

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SUMMARY - The first industrial-scale non-electric uses of geothermal heat date back to 1827, at Larderello. However, as opposed to electricity generation, this form of utilisation developed very slowly, and it is only in recent years that it has become of any real significance. At the moment direct uses of geothermal heat in Italy consist of space- and district-heating, greenhouse heating, fish farming and some industrial applications. The total installed capacity is about 220 MW_t, excluding bathing and swimming.

1. HISTORICAL BACKGROUND

The earliest forms of utilisation of natural heat, such as cooking food, probably date back to pre-historic times, although there is no archeological evidence as such. According to Cataldi and Chellini (1995), the Etruscans are the "historical fathers" of the geothermal industry, but the first example of what would be regarded as an industry nowadays did not appear in Italy until the early 19th century.

In the early 1800s a chemical factory was set up in the zone now known as Larderello, to extract boric acid from the hot waters flowing naturally or from specially drilled boreholes. The boric acid was produced by evaporating the hot fluids in iron boilers, using local wood as fuel. In 1827 Francesco Larderel, founder of this industry, invented a system for utilizing the heat of the boric fluids in the evaporation process, rather than the wood from the rapidly depleting forests (Fig. 1). Following on improvements to the production process, the amount of boric acid produced reached a total of 1000 tons in 1850 and 2000 tons in 1860. For the next 10-15 years the boric acid produced at Larderello penetrated the European market so well that it practically held a monopoly on the industry (Burgassi, 1987). Larderello's domination of the market ended around 1875 when its rivals, in the USA in particular, began producing boric acid from sedimentary-derived borates. During the last two decades of the 19th century the factory at Larderello also produced ammonium sulphate from the ammonia in the residual borate brines, and borax from the process reaction between boric acid and sodium carbonate. By 1920 chemical processing of geothermal fluids had further diversified to include new products such as sodium perborate, ammonium carbonate, carbonic acid, talcum powder and other compounds used in the pharmaceutical industry. The chemical factory operating at present at Larderello still utilises the heat of the geothermal fluids to process imported boric minerals.

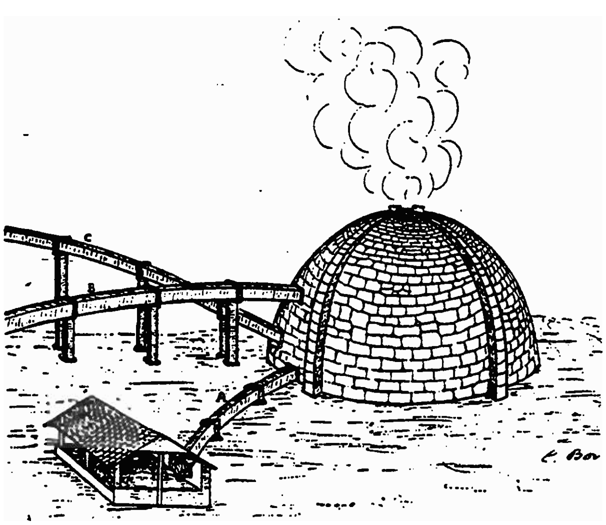

Figure 1 - Covered lagoon, the brick structure used at Larderello in the early 19th century to extract boric acid using the heat from geothermal fluids.

The mechanical energy of the natural steam was first exploited at Larderello in the late 19th century. The steam was used to raise liquids in primitive gas lifts, and later in reciprocating and centrifugal pumps and in winches, all used for well drilling or in the boric acid industry. Between 1910 and 1940 low pressure steam was gradually brought into use to heat the industrial and residential buildings, and the greenhouses at Larderello. At Acqui Terme the spring "La Bollente" was also used in the 19th century to heat greenhouses and, in the early 20th century, their local council offices.

2 PRESENT SITUATION

Practically all the geothermal non-electric installations now in operation in Italy have been listed in Table 1. This is an updated (courtesy of Enel for the most part) and slightly modified version of the table presented by Allegrini et *al.* (1995) at the World Geothermal Congress '95 in Florence. The data reported in Table 1, together with the descriptions that follow, which are

Table 1 - Utilisation of geothermal energy in direct uses in Italy (from Allegrini et *al.*, 1995, updated)

I=Industrial process heat
B=Bathing and swimming
F=Fish farming
G=Greenhouses
D=Space heating
*=See text

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

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

Locality	Type	Maximum Utilization					**Annual** Utilization		
		Flowrate	Temperature (°C)		Enthalpy (1) **(kJ/kg)**		Average Flow Rate	Energy use (2)	**Load** Factor
		kg/s	Inlet	Outlet	Inlet	Outlet	kg/s	TJ/yr	
1. Vicenza*	D	27.75	67	25			15.09	83.60	0.54
2. Rodigo	**G/F**	10.57	60	18			5.97	33.07	
3. Euganean Hills:									
Abano Terme	B/D	580.00	78	37			200.00	1081.58	
Montegrotto Terne	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
4. Acqui Terne	D	9.50	70	35			5.98	27.61	0.63
5. Ferrara*	D	55.60	100	60			31.70	167.25	0.57
6. Bagno di Romagna	**D**	**25.00**	**40**	**18**			**15.02**	**43.59**	**0.60**
7. Larderello:									
INA	**D**	**0.30**	**180**	**70**	**2755**	**293**	**0.08**	**6.12**	**0.26**
Industrial offices	**D**	**5.60**	**160**	**95**	**2780**	**398**	**1.89**	**141.87**	**0.34**
Montecerboli	**D**	**1.67**	**200**	**80**	**2423**	**335**	**0.38**	**25.12**	**0.23**
Monterotondo	**D**	**2.63**	**95**	**70**	**1000**	**293**	**0.76**	**16.92**	**0.29**
Villages	**D**	**1.95**	**160**	**95**	**2780**	**398**	**0.56**	**41.87**	**0.29**
SCL	**I**	**4.30**	**200**	**80**	**2860**	**335**	**2.99**	**238.36**	**0.70**
Bulera	**G**	1.00	120	**40**	1664	130	0.39	18.72	0.39
Lago	**G**	0.70	125	100	2730	419	0.17	12.56	0.25
Serrazzano	D	0.94	**200**	**80**	2438	335	0.21	14.23	0.23
Lustignano	D	0.33	200	**80**	2428	335	**0.08**	5.02	0.23
8. Castelnuovo:									
Isolver	D	0.016	117	70	2650	293	**0.005**	0.37	0.31
Castelnuovo town	D	7.60	105	70	1000	293	2.251	50.24	0.30
MAF (Forestry)	**G**	1.32	105	**70**	1000	293	0.66	14.65	0.50
MAF (Forestry)	**G**	2.80	70	30			1.351	7.12	0.48
Demonstration Centre	**G**	1.10	70	60			0.34	0.44	0.30
COSVIG	F	0.30	105	70	2685	293	0.10	7.56	0.33
9. Piancastagnaio	**G**	17.50	97	50	2200	209	6.94	435.44	0.40
10. Canino*	**G**	9.80	**40**	27					
11. Civitavecchia	**G**	238.00	52	30			58.19	168.86	**0.24**

derived in part from Sommaruga and Verdiani (1995) and Burgassi *et al.* (1995), and in part from the operators, give a comprehensive picture of direct uses of geothermal energy in Italy. There may be some small discrepancies between the data given in Table 1, and those given below, caused by the difference sin sources. We will describe the installations in the same order as they are listed in Table 1; the numbers in brackets refer to the numbers in the Table. Figure 2 shows the location of the installations written in italics below.

The *Vicenza* project (1), for space-heating in winter and air-conditioning in summer, was launched in the early 1980s and began regular service in 1990. The water comes from a limestone aquifer tapped at 2150 m by a borehole drilled in 1983 for oil research. The borehole produces 100 m^3/h of water at 67 °C with a low salt content of less than *0.5* g/l. The temperature of the water is adequate for supplying hot sanitary water and, with such a low salt content, can be distributed directly to the users. However, it is not warm enough for space-heating, as the plants are designed for an average temperature of 80-90 °C, and is therefore boosted by heat pumps and boilers. The heat pumps are installed next to the well and can be operated either by electricity or natural gas. After utilisation the water is discharged at 20 - 25 "C. The plant has been designed to provide space-heating in the winter months and air-conditioning in the summer, as the heat pumps are reversible. The plant has a power capacity of 4.88 MW_t and can heat a volume of 1,200,000 m3, with an energy savings of more than 3000 OET/year. Although it was a technical success, this plant has unfortunately been shut-down temporarily, for administrative and economic reasons.

The plant at ***Rodigo*** (2) utilises a 5000 m borehole drilled during oil research in 1975 and made available to the municipal authorities of Rodigo in 1989. The artesian well produces about 80 m^3/h of water at 59 °C with 0.73 g/l of salinity from a limestone aquifer at approx. 4000 m depth. If necessary, flow-rate can be increased to 120 m^3/h using a line-shaft pump, and to 250 m^3/h with a submersible pump. The cascade installation is used for space-heating, greenhouse heating, drying, fish-rearing and soil irrigation, varying the uses from season to season. During the winter the hot water from the well is used (at 58 °C) to heat some of the offices and work areas, as well as about 20,000 m^2 of greenhouses producing vegetables and flowers. After leaving the greenhouses the water is mixed with cold water and piped at 20-23 "C to the eel-breeding plant. Approximately 120 tons of eels are produced each year. Finally, at about 20 "C it is used for soil irrigation. During the summer the 58 °C water is piped to the hay or corn dryers. The installation has an installed capacity of 3.7 MW_t and the energy savings are estimated at 1200 OET/year.

The ***Euganean Hills*** area (3) covers a number of small towns that are famous for their spas - Abano Terme, Montegrotto Terme, Battaglia Terme and Galzignano being the most important. The thermal zone covers about 23 km^2, with 230 wells, most of which are 300 - 400 m in depth, that produce 65-87 °C water with the help of pumps. The annual average production of thermal water is 2500 m^3/h, most of which is utilised in the spas; however, it is also used for sanitary water supplies and space-heating in 126 of the many hotels in this zone. Each hotel has its own wells (usually 2, occasionally 3). The total volume heated is 2,500,000 m3, corresponding to an estimated energy savings of 25,000 OET/year. There are also 30,000 m^2 of greenhouses at Galzignano that utilise geothermal water (Carella, undated report). Part of these greenhouses has recently been shut-down temporarily to bring them into line with environmental regulations.

At ***Acqui Terme*** (4) the water emerges from a number of springs at temperatures between 55 and 74 "C, fed by a very deep hot aquifer (estimated temperature of 200 °C) through a system of faults. The main spring, 74 °C and flow-rate of 33.5 m^3/h, is used in winter in a district-heating plant equipped with heat pumps and with a total capacity of 4.6 MW_t, 1.3 MW_t of which is geothermal. The energy savings are estimated at 500 OET/year.

The geothermal district heating system at ***Ferrara*** *(5)* is one of the biggest in Europe. The water comes from an intensely-fractured limestone reservoir whose top lies at a depth of 1000 m, containing a brine (65 g/l) at temperatures around 100 "C. The hot water is pumped from a well drilled in 1981, and reinjected into an old borehole drilled during oil research, which crosses 1000 m of the aquifer. The geothermal brine is passed through heat exchangers near the wellhead, and the heated clean water is piped to the district heating system. The inlet temperature of the geothermal water at the heat exchangers is 98 °C and outlet temperature 68 "C. The district heating system is connected to the heat exchangers by buried insulated pipes totalling about *5* km in length. The system is integrated by the heat supplied by a municipal waste incinerator plant, and during peak periods or emergencies an auxiliary methane burner is available. Each user (residential building, school, hospital, etc.) has its own heat exchanger of appropriate size, connected to the main distribution system. Sanitary water is also supplied. At the end of 1995 a second well was put into production, with similar characteristics to the well drilled in 1981, but a slightly lower flow-rate. The upgraded system is still being monitored, so the relevant data in Table 1 refer to the situation prior to the new well. However, the area heated by the system at the end of last year had reached a total of 2,100,000 m3.

At ***Bagno di Romagna*** (6) the district heating system is supplied with water from a spring (43 "C) and 3 wells (average temperature of 40 "C) from depths ranging between 80 and 200 m, and a total flow-rate of 90 m^3/h. From March to November part of the hot water is used in the facilities of a spa, and during the rest of the year it is used to heat houses, hotels and public buildings (202,400 m^3), boosted from 40 °C to 76 "C by heat pumps. The system is integrated by the heat

Figure 2 - Non-electric geothermal plants in Italy

from a co-generation plant. The district-heating system has an installed capacity of 3 MW_t, about half of which is geothermal-derived.

As we said earlier, direct uses have existed in the ***Larderello*** (7) and ***Castelnuovo*** (8) zones since the last century. Both zones form part of what is generally referred to nowadays as the Larderello geothermal field. The installations utilise fluids with temperatures between 70 and 200 "C that are discharged from the geothermal power plants or, in a small percentage, produced from wells that are unsuitable for electricity generation. At the moment there are 9 district- or space-heating systems in service in the area, along with 5 greenhouse complexes, 1 industrial plant and a small fish-rearing station. The industrial plant, which uses geothermal heat to process imported boric minerals, is the last surviving trace of the chemical industry set up by Francesco Larderel in the early 19th century. Lustignano, Montecerboli and Serrazzano heating systems began operating after the World Geothermal Congress in 1995. A total of about 55 MW_t are now installed in the Larderello geothermal field for non-electric applications.

Piancastagnaio (9) is the site of one of the largest geothermal greenhouse complexes in Europe, which utilises the heat from the 96 "C fluid discharged from the geothermal power plant at Piancastagnaio. The greenhouses are located at a distance of 3 km from the power plant, and at a lower elevation (350 m lower). The heat transport system consists of three loops linked by two sets of heat exchangers. The first loop contains the corrosive waste fluid from the power plant, and is located right next to it. The second, closed loop, containing fresh water, runs downhill to the second set of heat exchangers near the greenhouse complex. The second loop was required to support the hydrostatic head caused by the 350-m difference in elevation between the plant and the greenhouses. The third loop, also a closed loop containing fresh water, distributes heat to the greenhouse units. The water enters the third loop from the heat exchangers at 80 °C and exits at 40 °C. Back-up heating is provided by fossil-fuelled heaters during peak periods and emergencies. The total covered area in the complex is now 250,000 m^2. The total installed geothermal capacity is 34.9 MW_t, for an energy savings of about 15,600 OET/year.

Since 1984 eight small demonstration greenhouses have been in operation at ***Canino*** (10), with a total covered area of 1600 m^2 and installed capacity of 0.22 MW_t. The heat was provided by a nearby spring, producing hot water at 40 "C and a flow-rate of 10 l/s, and connected directly to the plant. The data reported by Allegrini ***et al.*** (1995) refer to this group of greenhouses. In spring 1996 a new plant was put into operation (5 greenhouses covering a total of 1056 m^2 and an installed capacity of 0.47 MW_t), sited between the spring and the older plant. The new plant is heated directly by the spring water (inlet temperature of 40 °C and outlet temperature of 27 "C), and the old plant by the water discharged from the new installations and/or by the spring, through a by-pass. The data shown in Table 1 refer to the new plant.

The second most important geothermal greenhouse complex in Italy is at ***Civitavecchia*** (11), where the greenhouses cover an area of 180,000 m^2. Heating is provided by six wells that produce water of 45 - 52 "C from a limestone aquifer at a depth of 350 - 500 m. The plant has a total installed capacity of 30 MW_t and permits an energy savings estimated at 10,500 OET/year.

The following direct applications are indicated in Fig.2, but are not reported in Table 1 (nor in Allegrini *et al.*, 1995).

At ***Bormio***, a few kilometres from the Swiss border, several springs producing 34°- 43 "C water are used in spa facilities, and also to heat the spa and other buildings, through coils under the floor.

Near ***Orbetello*** is one of the biggest fish farm consortiums in Europe. Four farms, with a total of about 60,000 m^2 of tanks, produce approximately 700 tons of fish annually for the domestic market. Optimal temperature in the tanks is maintained by means of 45 wells of less than 100 m depth, which produce water at 17° - 25 "C. The water is mixed automatically to bring it down to the required temperature, oxygen is then added, and it is discharged into the sea. The farms breed sea bass and sea bream, as well as mullet in the discharge canals. With controlled temperature conditions, growth can be increased by 20 - 30%. The 4 farms have a total installed capacity of about 50 MW_t and permit energy savings of an estimated 17,000 OET/year.

Direct uses on a more or less family-run scale can also be found near the mouth of the river Tagliamento, about 60 km north-northeast of Venice, where fresh water at temperatures between 25" and 54 "C emerging from some shallow artesian wells is used to heat private houses and a few small greenhouses, and in crop dryers. On the island of Ischia, in front of Naples, there are a large number of thermal springs, whose hot waters are used in balneotherapy, to heat a few hotels, and for bottle-washing in a small wine-making firm.

New plants are being constructed in the ***Larderello -Castelnuovo*** zone (district-heating), and at Castelgiorgio and Latera (greenhouses), the latter two located about 100 km northwest of Rome. It is likely that the project for the island of Pantelleria, between Sicily and Tunisia, will eventually be implemented. An exploratory well on the island has met with high-temperature fluids (260 "C) that could be used in a desalination or electricity generation plant. Another project that is at an advanced stage, and likely to be implemented in the near future, is that of the CNR (National Research Council) Research Centre in Pisa, a complex that will house all the CNR research institutes and laboratories now spread over Pisa. Two directional wells are scheduled for drilling on the same site, one for production and the other for reinjection, and the target is a reservoir at about 900 m depth, containing fluid at ~ 70 °C and a predicted flow-rate of 200 t/h. The objective of the first phase of *this* project is to install a 7 MW_t plant to heat the 220,000 m^3 of the Research Centre; objective of the second phase is to add heat pumps and increase the installed capacity to 18 MW_t, to heat residential buildings in the neighbourhood.

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