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Geothermal Development In Italy: From Present To Future

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ABSTRACT

The contribution given by the geothermal heat to the total Italian energy consumption in 2006, though notable for the electrical generation, has been poor for the direct uses. The situation at December 2006 was as follows: 810 MW_e installed capacity with 5.52 gross electric energy generated, and about 650 MW_t installed capacity with some 8000 TJ/yr thermal energy produced for direct applications. The whole of such uses enabled saving almost 1.3 Million OET, of which 85 % ascribable to high-temperature fluids for electrical generation, and the rest to medium-to-low temperature fluids for direct applications.

As to the future, two possible development scenarios are presented for the use of the Earth's heat up to 2020, for which we forecast that, as compared to the above-said situation of 2006, the geothermal-electrical generation can increase 1.5-1.8 times more, whereas the whole of direct uses can have a much faster growth rate and increase 6-9 times more than the present value.

Based on these growth scenarios, it can be estimated that geothermal uses in Italy will aggregately enable saving in 2020 from 3 to 4 Million OET, which is roughly 3 times more than the present value. At the same time, the whole of such uses will avoid discharging into the atmosphere in 2020 an amount of CO_2 in the order of 8 million t/yr.

1. INTRODUCTION

Total gross energy consumption in Italy in 2006 has been about $200x10^6$ OET. Among the different contributing sources, the total is broken down as follows: 87% from fossil fuels (mostly oil and natural gas, and subordinately coal), 6% from imported electricity, and 7% from renewable and non-conventional energy sources [1]. Among the latter sources, the fraction coming from the natural heat has represented in 2006 some 0.6% of the total, with more than four fifths of the fraction attributable to high-temperature fluids used to generate electric energy, and the rest to medium-to-low temperature fluids used for direct applications.

Contrary to a so small share of the Earth's heat as against the total country's energy consumption, the Italian geothermal potential down to economically convenient depths is huge, with high-temperature resources (>150°C) concentrated in the Tuscan-Latium-Campanian pre-Apennine belt and in some of the Tyrrhenian volcanic islands (Fig.1), and medium-to-low temperature resources (< 150 °C) located in the same zones and in many other zones of Italy.

The first systematic geothermal ranking of the Italian territory was carried out in 1988 to draw up an inventory of the national geothermal resources [2-3]. The study, still valid today, enabled making the geothermal characterization, delimiting the extension, and classifying the promising areas as a function of the reservoir temperature according to their interest for the generation of electric energy and/or for the main types of direct use.

Moreover, the geothermal exploration conducted by ENEL and AGIP in the 80ies and 90ies of the past century led to confirm the existence of several areas in Latium, Campania and in some volcanic islands of the southern Tyrrhenian Sea, featured by reservoir temperature above 250 °C but very low permeability, or with fluids unsuitable for an economic generation of geothermal-electric energy. From the latter point of view, the most attractive areas resulted to be Larderello, Travale-Radicondoli and Mt. Amiata; whereas many other areas exist in Italy and are suitable to harness moderate-to-low temperature fluids for a number of direct uses.

Despite its geological situation favourable to harness any kind of geothermal resources, geothermal-electric generation only has received until few years ago a high attention in Italy, bringing it to reach in 2005 about 1.9 % of the total electric production [4]. The direct uses, on the contrary, have regrettably remained in the background, except thermal balneology which has continued to grow significantly also in recent years.

In consideration of the above, and taking into account the shortage of primary energy sources of Italy, as well as the increasing difficulties to meet the energy demand, together with the need to reduce the impact of greenhouses gases on the environment, UGI has started a promotion campaign mostly directed to the government, the political parties and the institutions in order to solicit them to introduce legal and administrative measures facilitating an accelerated development of the Earth's heat in all its possible utilization forms, with particular reference to the direct uses. The campaign is also addressed to the public at large aimed at making them aware of the advantages offered by the widespread use of the geothermal energy, in particular for the district heating in winter and for cooling in summer.

Starting from the situation at December 2006, this paper presents and discusses the objectives that according to UGI can be set for the development of the Earth's heat in Italy up to 2020, both for geothermal-electric generation and direct uses.

2. SITUATION AS OF DECEMBER 2006

2.1 Generation of Geothermal-Electric Energy

This generation is concentrated at present in Tuscany only, in the Provinces of Pisa, Grosseto and Siena (Fig. 2). Details of the power plants are given in Table 1 [5].

Some new units of the Nuova Larderello 3 and Nuova San Martino power plants came into operation in 2005, for an aggregate capacity of 60 MW_e in substitution of two old units for a total of 40 MW_e. Therefore, the whole geothermo-electric capacity installed in Italy at the end of 2006 is 810,5 MW_e (711 MW_e efficient capacity); the yearly net electricity generation is about 5200 GWh. This represents almost 10% of the world geothermo-electric generation [6], and about 76% of the same generation in Europe [7]; moreover, if referred to Italy only, the 5200 GWh mentioned above enable meeting 25% of the entire electric demand of Tuscany, and correspond to some 1,9% of the total country' electricity produced [4].

Drilling new wells in the last few decades in substitution of those whose output and pressure had underwent a notable reduction in time, together with drilling other new wells to depths in the order of 4000 m, led to an appreciable increase of the geothermal-electric production. Moreover, deep drillings enabled to confirm the working hypothesis made many years ago that the two adjoining production areas of Larderello and Travale-Radicondoli, though representing two "fields" separated at surface, are joined at depth in a sole geothermal system; therefore, Larderello and Travale-Radicondoli are two sub-systems of the same system. Furthermore, reinjection in non-productive wells of water obtained from condensation of steam exhausted by the power plants, resulted in slowering and partly compensating the natural decline of the fluid pressure in the reservoir, and enabled increasing the total output of the steam.

The Larderello "field", with about 200 production wells, over 3000 t/h superheated steam at temperature of 150-270 °C, weighted mean of incondensable gas 3.1 % in a range 1-10 % by weight, production pressure 0,2-1,8 MPa, is the most important area of geothermal-electric generation in Italy. It is followed by the adjoining Travale-Radicondoli "field", with 25 production wells, almost 1100 t/h superheated steam at 190-250 °C, with an average content of 5% incondensable gas in range 1-8%, and production pressure of 0,8-2 MPa.

The fields of Piancastagnaio and Bagnore, located in the southern slopes of the Mt. Amiata volcano, on the contrary, are water-dominated fields at depth up to 2500 and 4000 m, respectively, reservoir pressure about 20 MPa and temperature of 300-350 °C. The fluid produced by 16 wells is a double-phase mixture of water, steam and gas, which is separated at well head at a pressure of about 2 MPa. Its incondensable gas content is 8% by weight in a range 5-10 %.

Energy produced in all the aforesaid fields comes from 32 electrical generators, whose regional distribution, commissioning year, number of units per power plant, and gross and net capacity are shown in Table 1. It can be seen that 12 out of 32 units have been newly installed or modernized in the period 2000-2005, proving the notable effort made by Enel in the last few years to increase the efficiency of their geothermal-electric plants.

Electricity generation from the end of 1999 through 2006 increased by about 800 GWh, i.e. a 18% aggregate increase, whereas the running capacity in the same period grew by only 63 MW_e, i.e. 8% total increase. Therefore, such important result is manly due to the modernization and enhanced efficiency of 12 generating units, as well as to the positive results of reinjection strategy and to the successful drilling of a number of deep wells (about 4000 m).

From the environmental viewpoint, it is worth recalling the recent installation in most important power plants of special equipment to abate hydrogen sulphide and mercury contained in the incondensable gases drawn by the geothermal steam. This measure, together with the effectual insonorization of rotating machinery, cooling towers and drilling rigs, as well as other environmentally-focussed measures, have definitely improved the social acceptability of the geothermal activities by the residents in the production zones.

2.2 Direct Uses

We have already mentioned that, despite their wide application possibities, the direct uses have raised scarce interest so far in Italy, except thermal balneology which has continued to grow at a sustained pace. However, we should also mention that, because of the increase in price of oil products, the Italian institutions and some public investors have started to pay attention in the last few years at the renewable and non-conventional energy sources, including geothermal energy. In fact, utilization in 2006 of the latter source (see Table 2) is roughly doubled as compared to the situation in 1999-2000: present capacity is 650 MW_t for the plants supplied by natural heat vs. about 325 MW_t, which makes approximately 39% annual capacity factor vs. 37%, and a total production of 8000 TJ/yr vs. 3800 TJ/yr.

Concerning geothermal heat pumps in particular, it is estimated that their total capacity at December 2006 was in the order of 150 MW_t, with about 600 TJ/yr of thermal energy produced. This corresponds to some 23 % of the total installed thermal capacity, and to 7.5% approx. of the energy produced: a still unsatisfactory value as compared to their wide application possibility. Nonetheless, we should say that the use of this technology has started to take root, as proved by a number of initiatives completed or underway in several towns of northern and central Italy. The most significant of these initiatives are two urban tele-heating projects using heat pumps supplied by phreatic or surface waters at temperature less than 15 °C. The first of these projects is being implemented at Milan [9], and the second at Bergamo [10], both in Lombardy.

The principal utilization sectors of the geothermal heat are listed in Table 3, whereas the regional distribution of the total uses is given in Table 4.

The most important district heating project put into practice so far in Italy is heating hundreds flats in the centre of Ferrara, a historical town in Emilia. Heat is derived from combined energy sources, including urban solid wastes, geothermal heat, and a co-generating plant. Geothermal heat is supplied by water at about 95 °C pumped from a 1300 m deep aquifer by two wells sited some 4 km far from the centre of the town [11]. Each well delivers about 200 m3/h of hot water which feeds heat-exchangers installed at the well-head of each well, before being reinjected into the same aquifer through a third well located 1 km away from the production wells. Saving of fossil fuel is in the order of 6600 OET/yr [11]. The same type of heating might be progressively extended to most of the town by drilling other wells to tap hot water from the same aquifer.

In the greenhouse sector, the most important geothermal realization is found in the Mt. Amiata region, about 3 km to the South of Piancastagnaio. Here, the steam exhausted by the local power station is condensed to obtain water at 90°C which, before reinjection, feeds a heat-exchanger with a fresh-water loop circulated though it in order to supply heat

to a large greenhouse complex (230,000 m^2). Saving of fossil fuel in this project is about 12,000 OET/yr [8].

Greenhouses fed by geothermal heat are also found in other zones of Tuscany, and in Veneto, Latium, and other Italian regions; the surface extension of each greenhouse, however, is much less than that of the above-said complex [8].

3. PROSPECTS UP TO 2020

Forecasts of geothermal growth in Italy until 2020 are presented in the framework of two development scenarios: the first based on the present situation of the energy market, with the use of existing technologies and hypothesizing that the concerned institutions will take suitable measures to accelerate deep exploration in new promising areas; and the second scenario based on the intensive use of the natural heat in energy market conditions more difficult than the present ones, with the contemporary adoption of an ecologically-driven energy policy, and with the encouragement to apply strongly innovative technologies. Therefore, the forecasts given below represent a fork of growth targets that should be considered, in the first case a probable, and in the second case a possible objective.

3.1 Geothermal-electric Generation

Starting from the situation at December 2006 the growth forecasts up to 2020 can be referred to two temporally distinct phases (Fig. 3), as follows.

The *first phase*, until December 2012, refers in part to the implementation of operative plans in the fields of Larderello, Travale-Radicondoli, Bagnore and Piancastagnaio and in their surrounding areas. They include modernization of old units and installation of new groups, for a possible aggregate additional capacity of about 150 MW_e. Thus, by December 2012, it is estimated to have:

- Total installed capacity: about 960 MW_e
- Annual gross generated energy: some 6 billion kWh.

The *second phase*, from 2013 to 2020, includes exploration and drilling in some promising areas in southern Tuscany within and outside the afore-said fields and their neighbourhood, as well as in other high-temperature areas in central and southern Italy. With such activity, an increase of 25% of the figures above can be estimated in the case of the *first development scenario*. Consequently, for December 2020 we forecast:

- Total installed capacity: about 1200 MW_e;
- Annual gross electric generation: some 7.5 billion kWh.

However, considering the geothermal development in the light of the *second, ecologically-driven, scenario*, with the application started of more advanced technologies (EGS / Enhanced Geothermal Systems, binary cycles by using moderate-temperature fluids, and others), a further 25-30% increase of the figures above is possible, resulting in the following values by December 2020:

- Total installed capacity: about 1500 MW_e;
- Annual gross electric generation: some 10 billion kWh.

In short, the increase of the Italian geothermal-electric generation by the end of 2020 can be estimated at values 50-100% higher than those at December 2006 (810,5 MW_e installed capacity and 5.5 TWh/yr gross electric generation). This represents an average annual growth rate of between 2.5 % and 4.5% in the case of the first and second scenario, respectively.

3.2 Direct Uses

More than half of the Italian territory is characterized by geologic conditions favourable to the existence of moderate-to-low temperature geothermal resources. This situation points to wide development prospects for this type of resources.

On the other hand, to have an idea of the market possibilities for such development, it should be recalled that more than 95% of the space heating in Italy in 2005 has been met by burning fossil fuels (mostly natural gas, and subordinately oil), with less than 5 % of the heat provided by renewable and non-conventional energy sources [1]. Among the latter sources, the contribution of geothermal energy amounted in 2005 to 1714 TJ against 1,400,000 TJ (33 Million OET) consumed in that year for space heating, which is about 0.1 % of the total energy used for space heating. This is an unsatisfactory situation from both economic and environmental viewpoints, which should open the path to a fast increase in the use of the natural heat for space heating in winter, and space cooling in summer. Moreover, in addition to district heating, many other application possibilities exist to use the Earth's heat by both traditional technologies and heat pumps.

In consideration of the above, and to allow for a certain flexibility, forecasts are presented in Table 5 for the whole of direct uses according to two possible growth scenarios, similar to those considered for the geothermal-electric generation, i.e. the first scenario based on the present energy economy and technology, and the second scenario seen in the frame of an ecologically-driven development, and with the application of more advanced technologies. Thus, the figures given below represent a fork of values between reasonably sure minima and possible maxima.

This table shows that the estimated increase of the whole of direct uses in 2020 is in the order of 6.5 times more than the figures at December 2006 for Scenario I, and of 9-10 times more for Scenario II.

Even though the total values given for the end of the period do not seem impressive enough if considered in the light of the total energy consumption expected in Italy by 2020 (which will likely exceed the present $200x10^6$ OET), nonetheless they are important values if compared to the modest development that the same uses had in Italy till 2006. In fact, the average growth rate for the entire period ranges from 14 to almost 17% per year, with an avoided consumption of fossil fuels of between 1.2 and 1.8 million OET.

4. SUMMARY AND CONCLUSIONS

Electric generation from geothermal energy in Italy is at present confined in southern Tuscany, in the fields of Larderello, Travale-Radicondoli and Mt. Amiata (Fig. 2). As to the future, favourable prospects for such generation may arise from deep drilling in these fields and in their surrounding areas, as well as from a few other continental and insular areas.

Concerning the type of resources, since no EGS technologies are mature as yet at the commercial scale, we think that, for another five years at least, high-temperature hydrothermal systems only will contribute to the geothermal-electric generation in Italy, whereas the

technologies above might start becoming commercial in the second part of the next decade.

On the other hand, from one side the aggregate surface area of the high-temperature hydrothermal systems is in the order of 1500 km^2 only (i.e. much less than 1% of the whole Italian territory), and from the other side a number of non-technical constraints exist which hamper at present the full development of certain fields. Therefore, we feel that, even in the framework of the second scenario, the geothermal-electric generation in Italy could hardly grow by the year 2020 more than two times of the present production values [12-13].

On the contrary, favourable geological conditions exist in all areas cited above and in many other areas of the national territory enabling the technical feasibility to harness large amounts of terrestrial heat for direct applications. At the same time, wide prospects exist in the above-said areas to create a sustained demand of natural heat for such applications, especially for space conditioning. Therefore, both basic conditions (large availability of resources, and important potential consumption poles) are met in many areas of Italy for a fast development of the natural heat in the next future.

Table 6 summarizes and allows comparison between the maximum growth figures forecasted for the production of geothermal-electric energy and for direct applications until 2020 as against the situation at December 2006. The table also shows the savings of fossil fuels, the combined shares on total energy consumption, and the avoided discharge of CO_2 into the atmosphere.

Regardless of the approximation of the forecasts made, this table shows that:

- total utilization of the geothermal heat (including electric production and the whole of direct applications) is expected to triplicate in the year 2020;
- direct uses have much higher possibilities of development than those of the geothermal-electric generation. As a consequence, saving fossil fuels by using terrestrial heat directly will almost equal in 2020 that of the geothermal-electric generation, and will likely surpass it in the following years;
- the quantity of CO_2 that (mostly thanks to the direct uses) will not be discharged into the atmosphere in the year 2020 (in the order of 8 million t/yr), may seem negligible as compared to the total foreseeable amount of CO_2 produced in Italy in that year; but it is not negligible at all, neither in absolute nor in relative terms, if compared to the CO_2 released by the equivalent fossil fuels that geothermal resources are expected to substitute in that same year.

In consideration of the above, UGI has prepared and is about to launch a document called ***The Italian Geothermal Manifesto***, directed mostly to political parties and to institutions involved in energy matters, aimed at urging them to create suitable measures to stimulate the massive development of the low-to-moderate temperature resources. Should these measures be taken quickly, the objectives indicated above for Scenario I, could in our opinion, be easily met, and could be likely pursued also the objectives set forth by Scenario II.

At any rate, achievement of these objectives would lay the ground for the implementation of much more ambitious development plans of the geothermal heat in the decades beyond the 2020.

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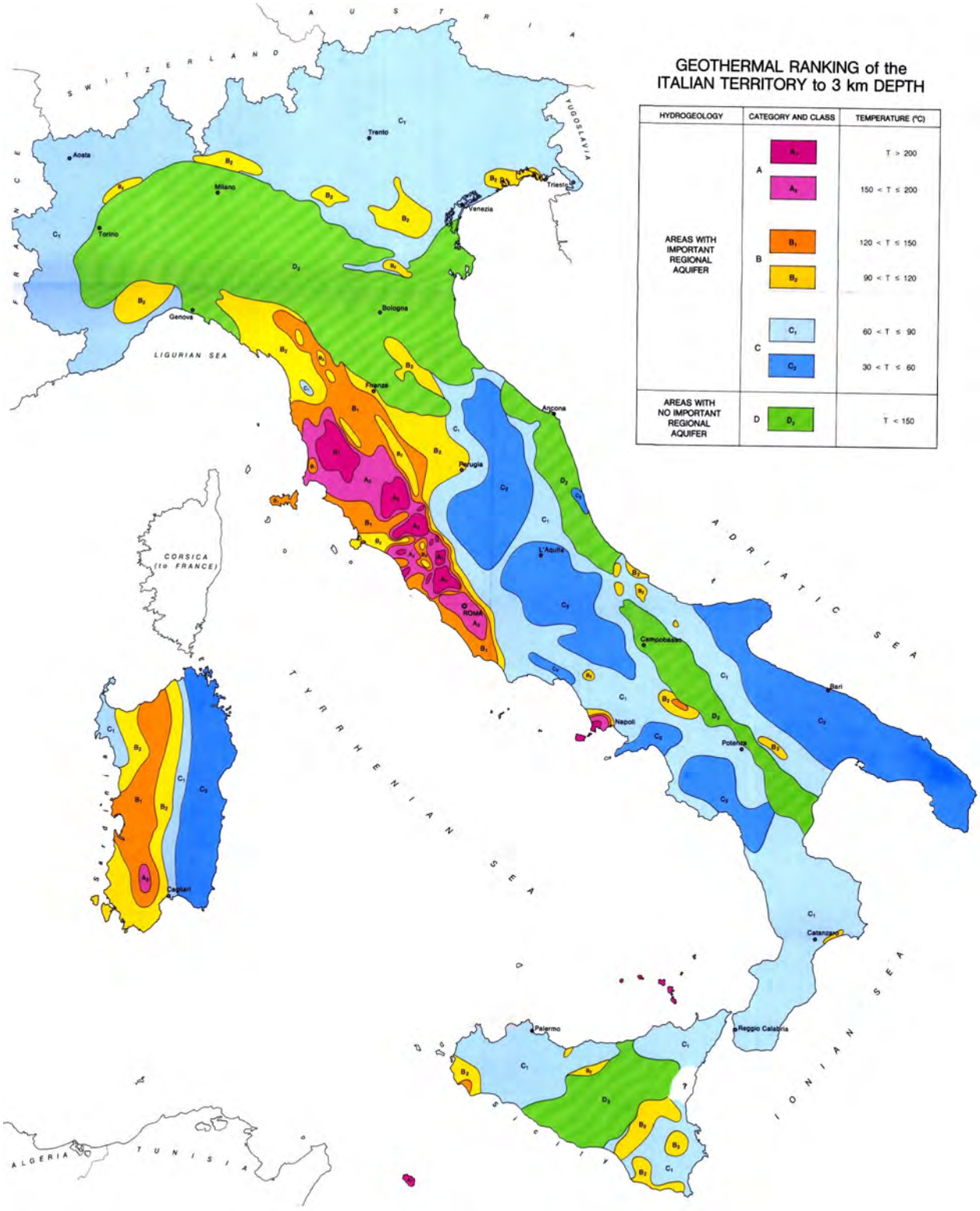

Fig.1. Geothermal ranking of the Italian territory

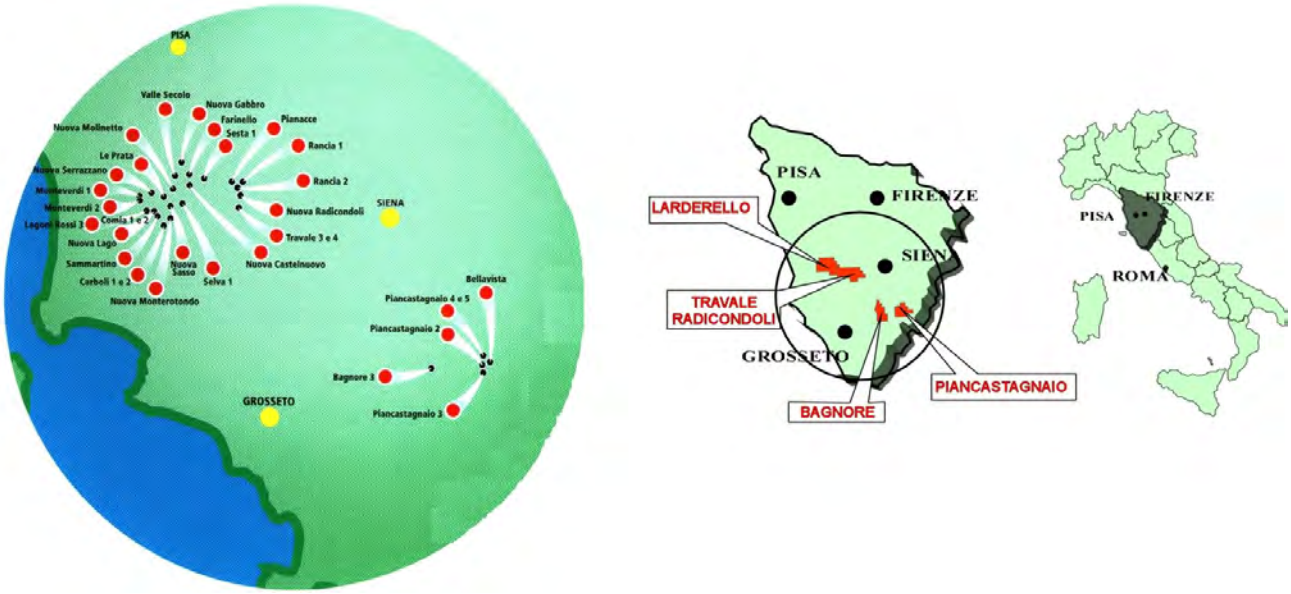

Fig. 2: Location of the Italian geothermal-electric power plants

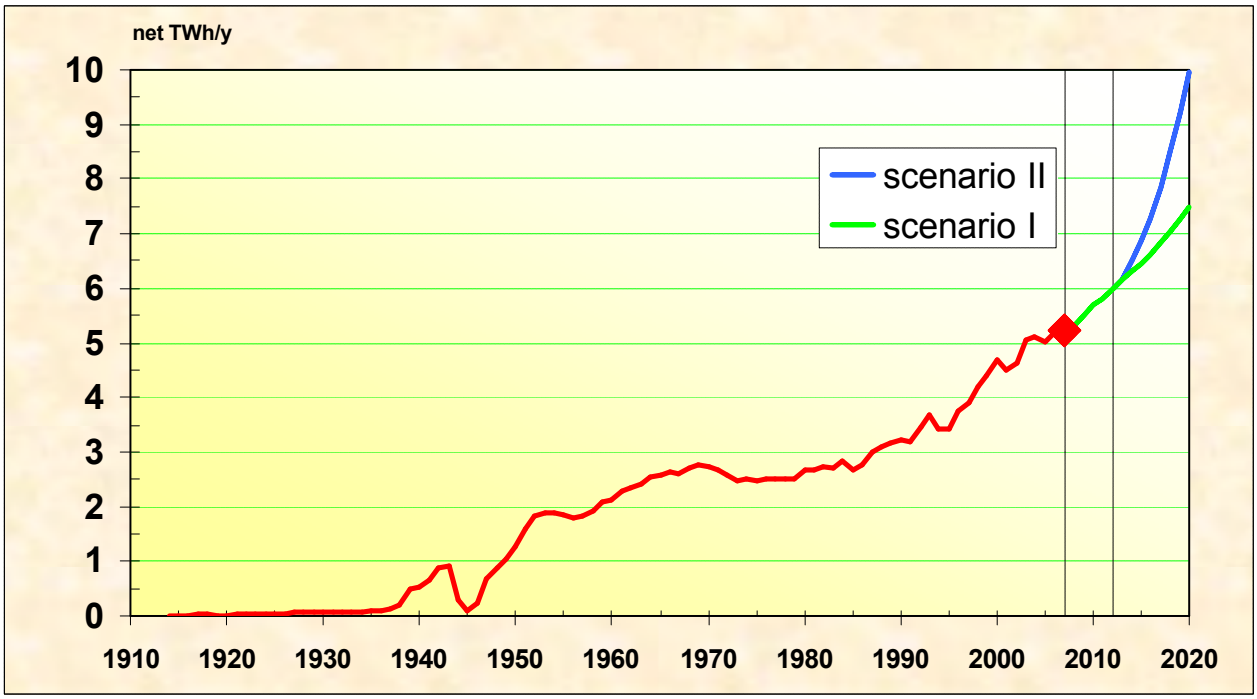

Fig. 3: Geothermal electric generation in Italy since 1913 and forecast to 2020.

Table 1: The Italian geothermal power plants as of December 2006

(after Cappetti-Ceppatelli, 2005 ***[5]*** *, with updating)*

Location	*Name of the power plant*	*Year of commissioning*	*Number of units*	*Total installed capacity* **MW_e**	*Net capacity* **MW_e**
Larderello	Valle Secolo	1991	2	120	114
	Farinello	1995	1	60	46
	Nuova Larderello 3	2005	1	20	15
	Nuova Gabbro	2002	1	20	19
	Nuova Castelnuovo	2000	1	14,5	14
	Nuova Serrazzano	2002	1	60	47
	Nuova Sasso	1996	1	20	15
	Le Prata	1996	1	20	15
	Nuova Monterotondo	2002	1	10	8
	Nuova San Martino	2005	1	40	36
	Nuova Lago	2002	1	10	10
	Lagoni Rossi 3	1981	1	8	6
	Cornia 2	1994	1	20	14
	Nuova Molinetto	2002	1	20	17
	Carboli 1	1998	1	20	19
	Carboli 2	1997	1	20	19
	Selva 1	1997	1	20	19
	Monteverdi 1	1997	1	20	16
	Monteverdi 2	1997	1	20	16
	Sesta	2002	1	20	17
Subtotal			**21**	**563**	**482**
Travale Radicondoli	Nuova Radicondoli	2002	1	40	38
	Pianacce	1987	1	20	18
	Rancia	1986	1	20	18
	Rancia 2	1988	1	20	18
	Travale 3	2000	1	20	19
	Travale 4	2002	1	40	39
Subtotal			**6**	**160**	**150**
Monte Amiata	Bagnore 3	1998	1	20	20
	Piancastagnaio 2	1969	1	8	6
	Piancastagnaio 3	1990	1	20	19
	Piancastagnaio 4	1991	1	20	17
	Piancastagnaio 5	1994	1	20	17
Subtotal			**5**	**88**	**79**
TOTAL			**32**	**810,5**	**711**

Table 2: Geothermal direct uses in Italy in 2006. A summary.

- Total installed capacity (including heat pumps) ……..……..….ca. 650 MW_t
- Total thermal energy used (including heat pumps) ….……...ca. 8000 TJ/yr
- Average annual capacity factor ……..……ca. 39 %/yr
- Fossil fuels savings ……about 190, 000 OET/yr

Table 3: Main utilizations of the geothermal heat

Thermal balneology	35%
Space heating (district heating & others)	22%
Fish farming	19%
Greenhouse heating	15%
Heat pumps	8%
Industrial processes	1%
Total geothermal energy (ca. 8000 TJ/yr)	**100 %**

Table 4: Regional distribution of direct uses

Veneto	38,20%
Toscana	23,40%
Campania	9,50%
All others Italian Regions	28,90%
Total energy (ca. 8000 TJ/yr)	**100 %**

Table 5: Growth forecast of the whole of direct uses of geothermal heat in Italy up to December 2020.

(after Barbier et al., 2006 ***[12]****, with updating)*

	S C E N A R I O I			S C E N A R I O II		
Year	**Installed capacity (MW_t)**	**Geothermal energy used (TJ/yr)**	**Fossil fuel savings (OET)**	**Installed capacity (MW_t)**	**Geothermal energy used (TJ/yr)**	**Fossil fuel savings (OET)**
2006	**650**	**8000**	**192,000**	**650**	**8000**	**192,000**
2010	**900**	**11,200**	**270,000**	**1000**	**12,500**	**300,000**
2020	**4000**	**50,000**	**1,200,000**	**6000**	**75,000**	**1,800,000**
Average yearly growth rate 2007 - 2020 (%)		**14 %**			**17 %**	

Table 6: Summary of the growth forecasts of electric generation and direct applications by using the Earth's heat in Italy in 2020, as compared to the situation in 2006

	2006	**2020**
Geothermal-electric generation		
810 MW_e - 5.2 TWh/yr	1,100,000 OET	1500 MW_e - 10 TWh/yr	2,000,000 OET
Total direct uses		
650 MW_t - 8000 TJ/yr	192,000 OET	6000 MW_t - 75,000 TJ/yr	1,800,000 OET
Grand Total	**1,290,000 OET**		**3,800,000 OET**
Share on total energy consumption	0.6 %		> 1.2 %
Avoided CO_2	**2,700,000 t/yr**		8**,000,000 t/yr**