Geothermal development in Italy 2010-2030: a challenge to win

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ABSTRACT

Italian geothermal resources potentially harnessable on land within 5 km depth are ~ 21 EJ; but 30% max. of them have a sufficiently high temperature enabling economic power production. The rest (more than 70%, at T< 90 °C) are suited for direct uses only. Concerning high temperature fraction, maybe 20% of the max. 30% said above are associated with hydrothermal systems, whereas the other 80% are tied to *unconventional geothermal systems*: HDR/EGS, supercritical fluids, pressurized systems, magmatic systems, and hot brines. This means that a small fraction only of the Italian high-temperature geothermal potential is economically harnessable at present costs.

To assess what reasonable future could geothermal energy have in Italy, based on a thorough analysis of the geological and reservoir situation of all Italian geothermal resources, and on the expected technological-economic conditions related to their exploitation, starting from the situation at Dec. 2010, a study has been carried out by UGI on their possible development up to 2030. Projections have been made according to two different growth scenarios, a prudent one (Scenario I) and an ambitious one (Scenario II), with 5-by-5 year steps to make periodical checks. All types of systems (the hydrothermal ones and the above-said *unconventional geothermal systems*) have been considered for possible exploitation down to 5 km depth till 2030. For the *unconventional systems*, however, we have hypothesized that their technological and economic viability cannot be reached in Italy before the beginning of the next decade.

The main results of the study in question are summarized in this paper, including: *i)* geothermal potential to 5 km depth; *ii)* role of the Earth's heat in the national energy framework as of Dec. 2010; *iii)* geothermal development 2010-2030 and expected share in the framework of the total energy consumption supposed to occur in Italy by 2030; *iv)* technical, socio-economic, environmental, and scientific benefits expected from the development of geothermal energy; and *v)* measures required to achieving the targets envisaged.

With reference to the situation at Dec. 2010 (882.5 MW_e with 5.34 TWh/y for power generation, and 1000 MW_t with 12,600 TJ/y for direct uses), the forecasts at Dec. 2030 of geothermal development in Italy for the two growth scenarios said above are as follows:

Scenario I: 1500 MW_e with 9.4 TWh/y for power generation, and 7400 MW_t with 65,200 TJ/y for direct uses;

Scenario II: 2000 MW_e with 12 TWh/y for power generation, and 8800 MW_t with 90,000 TJ/y for direct uses.

From the figures above one can calculate that the total geothermal development in 2030 would increase by 2.5 and 3.4 times approx. (for Scenarios I and II, respectively) as compared to the situation at Dec. 2010. These values would represent 1.5÷2% of the total energy consumption guessed to occur in Italy in 2030, and CO_2 avoided emissions of between 10 and 13 million tonnes/year, approx.

1. BACKGROUND AND AIM OF THE PAPER

The need to carry out a study to estimate the geothermal resources potentially harnessable in Italy for power generation and direct uses dates back to 12 years ago, soon after UGI was created in February 2001. However, for several reasons, the study could not start until 2005 and was concluded in 2006.

The estimations made in that study (Barbier et al., 2006), with projections until 2020, were founded on two different growth scenarios: a prudent *Scenario I*, based on the then socio-economic conditions of Italy, and an ambitious *Scenario II*. The latter scenario was designed in the hope that: *a)* a new development process, driven by strong environmental policies, would start in 2007; and *b)* such policies would speed up the exploitation of all renewable energy sources, primarily the geothermal one, with which Italy is widely endowed .

On the other hand, since the cost of oil at source had grown at an average rate of 10% per year from 2000 to 2005, and all energy experts agreed that it was an irreversible upward trend, UGI assumed that such cost would reach 90-100 US $/bbl in 2010 and about 200 US $/bbl in 2020, resulting in an accelerated development of geothermal energy. With these hypotheses in mind the study mentioned above was revised and published as a second edition in late 2007 (Barbier et al., 2007), together with a flyer called *The Italian Geothermal Manifesto*. Both these documents were issued in Italian and English.

Albeit with some delays - which could be recovered in a matter of a few years - all assumptions mentioned above began vanishing upon the first signs, in late 2007, of the economic crisis that would heavily hit the world from 2008 onwards. As a result, the price of oil at source continued to mount in 2006-2007 with a hike in 2008, followed by a sharp decrease in the first half of 2009 and by a new increase in the second half of 2009, till reaching some 80 US $/bbl in 2010.

As a consequence, at the end of 2010, it was patent that the study revised in 2007 should be updated to account for: *i)* the small progress made in geothermal development owing to the detrimental effect of the crisis; *ii)* the change in the country's socio-economic framework; *iii)* the foreseeable strong increase in the cost of all energy sources; and *iv)* a number of other factors (adding to the crisis in point) which had dwarfed the growth in the use of the Earth's heat in Italy from 2008 through 2010.

Moreover, in line with the initiatives that the EU was taking in those years to accelerate the development of all renewables under its *20-20-20 Climate-Energy Packet*, and to provide Italian energy institutions with a wider vision of the potential share of geothermal heat in the coverage of the country's energy needs in the medium-long term, the estimates made in the previous study until 2020 were furtherly revised in 2011, with projections extended until 2030 (Buonasorte et al., 2011).

In this case, too, two different growth scenarios similar to those of the first and the second study were built: a prudent *Scenario I* and an ambitious *Scenario II*.

Therefore, based on the status of development at the end of 2010, the growth prospects of the Earth's heat extractable within 5 km depth were analyzed by 5-year periods until 2030. Moreover, the resulting technical-environmental and socio-economic benefits were evaluated, and the measures necessary to attain the targets set for 2030 were identified. Afterwards, in December 2011, the new study, its executive summary, and a flyer named *The New Italian Geothermal Manifesto* (the latter two documents in Italian and English) were published for wide dissemination in Italy and abroad. All these documents are the source of this paper that UGI now submits to the attention of the international geothermal family.

2. GEOTHERMAL FRAMEWORK AND POTENTIAL OF ITALY ON LAND, DOWN TO 5 KM DEPTH

Geologically, Italy was formed as part of the Alpine-Apennine orogen, resulting from the collision between the European and African plates, which began in the Upper Cretaceous (80-60 million years ago) and ended in the Upper Miocene (15-10 million years ago).

During the orogenetic process, starting some 15 million years ago, the opening of the Tyrrhenian Sea occurred as a result of mantle arching in the south-western Mediterranean, with the rising of igneous material from partly deep and partly anatectic magma bodies. This process, still under way, gives rise to: *i)* thinning of the crust; *ii)* formation of intrusive bodies; and *iii)* volcanic activity in the western margin of the Apennine chain from Tuscany to Campania, in the southern Tyrrhenian Sea, in central Sardinia, and in eastern Sicily (Fig. 1). As a result of the above, favorable conditions exist in Italy for the formation of an anomalous thermal regime, mostly in the southern Thyrrhenian Sea and in the pre-Apennine belt of central Italy, as can be seen in Figure 2.

Fig. 1: Main geodynamic domains and recent volcanism of Italy

This figure highlights two main sectors with a different thermal regime:
- a western and Tyrrhenian sector, with heat flow values of 80-450 mW/m^2;
- a northern/eastern/south-eastern and southern sector (Alps, Apennines, Adriatic-Ionian belt, Calabria and Sicily, with heat flow values of 20-80 mW/m^2.

Moreover, moderate values (100-150 mW/m^2) exist in the Sicily Channel (Pantelleria island) and in central Sardinia (from Cagliari to Sassari through the Campidano graben), both corresponding to the rift structures shown in Figure 1. All such values compare to a world average heat flow value of ~ 60 mW/m^2.

In brief, special conditions have formed locally as result of: recent geodynamics, igneous and tectonic processes (Fig.1), anomalous thermal regime (Fig. 2), and presence of impermeable complexes overlying permeable rocks with water circulation (confined aquifers). All these conditions gave rise to the formation of a variety of geothermal resources on land and offshore.

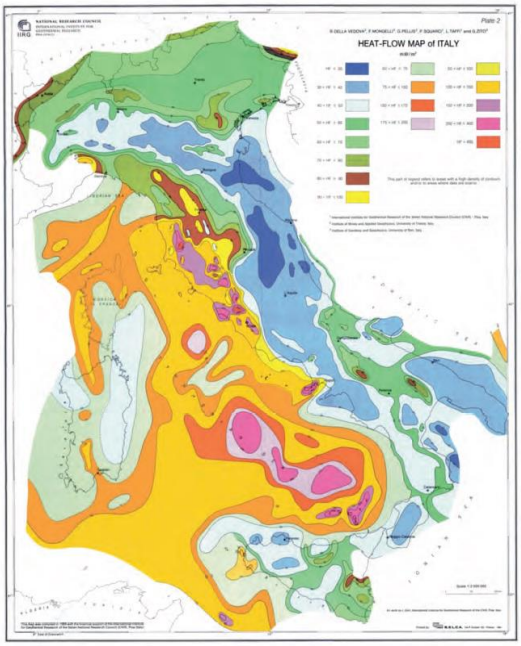

Fig. 2: Conductive heat flow in Italy

The resources on land potentially harnessable within 5 km depth are ~ 21x10^{18} Joule, corresponding to 500 million tonnes of oil equivalent-MTOE)[1]; two thirds of them have temperature below 150 °C.

However, resources at a temperature suitable for electricity generation (T > 80 - 90°C) at costs currently competitive with those of other energy sources exist only in areas with strong heat flow anomalies, namely in the Tuscany-Latium-Campania pre-Apennine belt, on the two main Italian islands and on some volcanic islands of the Tyrrhenian Sea, all located in western and south-western Italy (Fig. 2).

Conversely, medium- and low-temperature resources (T < 80-90°C) suitable for direct uses only are found in the above-said areas of high heat flow and in many other zones. Additionally, thanks to the use of heat pumps, even resources at very low temperature (T < 30 °C) and at small depth could be exploited almost everywhere in Italy.

[1] By comparison with the Italian situation, it is worth recalling that: *i)* the total Earth's heat is 8-12 x10^{30}J; *ii)* the world's geothermal resources harnessable on land down to 5 km depth are some 3.5x10^{21}J; *iii*) in geographic Europe, harnessable resources on land are about 6x10^{20}J. It follows that, regardless of temperature, the Italian geothermal potential down to 5 km depth accounts for 3.5% only of the overall European one.

The above infers that, within accessible depths, Italy is endowed with a huge potential of medium-to-low temperature resources, which could be tapped much more intensively than hitherto.

3. GEOTHERMAL DEVELOPMENT AT DECEMBER 2010

The situation at the end of 2010 can be summarized as follows.

3.1) Power generation

- capacity installed: 882.5 MW_e;
- gross generation: 5.34 TWh/y;
- oil saved: 1020 kTOE/y;
- avoided CO_2 emissions:: 3200 kTonnes/year.

The production areas were located in Tuscany only: in the Boraciferous region (with plants installed at Castelnuovo V.C., Larderello, Radicondoli, Sasso Pisano, Serrazzano, Montieri, and Travale, for an aggregate capacity of 794.5 MW_e), and in the Mt. Amiata region (with plants installed at Bagnore and Piancastagnaio, for a total capacity of 88 MW_e).
For better understanding what we will say later in this paper, it is worth recalling that the growth in geothermal power generation in the 5-year period from Dec. 2005 to Dec. 2010 was equal to 72 MW_e and 0.13 TWh/y, corresponding to an average increase of a little less than 2%/y in terms of installed capacity and of 0.5%/y in terms of power generation.

3.2) Direct uses *(total, including heat pumps)*

- capacity installed: 1000 MW_t;
- gross production: 12,600 TJ/y;
- oil saved: 300 kTOE/y;
- avoided CO_2 emissions: 800 kTonnes/year.

The growth in total direct uses in the 5-year period from Dec. 2005 to Dec.2010 was around 350 MW_t and 4400 TJ/y, corresponding to about 7% annual increase. This is a much more important yearly increase than that mentioned above for power generation.

The contribution of geothermal heat pumps to the above-said total annual increase for direct uses is rather difficult to evaluate because scarce and uncertain data are available on the number of heat pumps installed in 2005. For 2010, however, we can state that the operating capacity of geothermal heat pumps at December 2010 was in the range of 500 MW_t (out of 1,000 MW_t of total capacity for direct uses), whereas the heat produced was 1700 TJ/y (out of a total of 12,600 TJ/y for direct uses). This means that the share of heat pumps in total direct uses was 50% in terms of capacity and 13.5 % only in terms of heat produced.

3.3) Total utilization of geothermal energy

The data reported in points 3.1) and 3.2) above lead to say that geothermal heat (power generation + direct uses) in 2010 totaled 1320 kTOE, displacing 4,000 kTonnes of CO_2 emissions.

4. GEOTHERMAL VS. TOTAL ENERGY CONSUMPTION IN 2010

The total energy consumed in Italy in 2010 amounted to 185 MTOE: 83% from fossil fuels (oil, gas, coal); 5% from imported electricity; and 12% from renewables: large and small hydro, wind, geothermal, photovoltaic, and biomass.
The share of aggregate renewables climbed from 7% in 2005 to 12% in 2010 owing to the reduction of total energy consumption (from 198 MTOE in 2005 to 185 MTOE in 2010) and to the impetus given to their development in the past few years.

In particular, geothermal energy grew from 1.19 MTOE in 2005 to 1.32 MTOE in 2010. In that period, therefore, the geothermal contribution to the total energy consumed in Italy rose from 0.6 to 0.71%. The increase is mostly owed to direct uses of natural heat, which passed from 0.2 MTOE in 2005 to 0.3 MTOE in 2010: an average growth rate of 8.5% per year.

In contrast, though dominant over direct uses, power generation rose in the same period from 0.99 to 1.02 MTOE, i.e. at an average growth rate of as little as 0.6% per year.

The above figures clearly show that, from 2005 to 2010, geothermal deployment in Italy was rather poor as compared to the country's large geothermal potential, especially for direct uses.

5. DEVELOPMENT ENVISAGED BY 2030

5.1) General and Scenarios of development

In order to estimate the possible contribution of the Earth's heat (power generation + direct uses) to the coverage of national energy requirements by 2030, the new study mentioned before was carried out by UGI in 2011 and aimed at giving the Italian government updated factual elements on the medium-term deployment of this energy source in Italy. The study served also as a reference to prepare the text of a *New Italian Geothermal Manifesto* with a wider vision than that of the similar Manifesto published by UGI some five years ago. Moreover, to enable periodical revisions, the study defined targets at intermediate steps: end of 2012, 2015, 2020 and 2025.
Growth projections were formulated by taking into account: *i)* Italy's geological setting and geothermal resources known or supposed to exist down to 5 km depth; *ii)* likely sharp increase in fossil fuel prices in the next years; and *iii)* expected technological improvements in the utilization of the Earth's heat.

For the latter point, since *unconventional geothermal systems* (i.e.: EGS/HDR/HFR, magmatic systems, geopressurized systems, supercritical fluids and hot brines) are far from reaching technological maturity and thus enable commercial power production, we have assumed that, till the end of this decade, geothermal electricity can only come from high- or moderate-temperature hydrothermal systems. In other words, we have supposed that the *unconventional geothermal systems* in question cannot contribute to power generation in Italy within this decade, but that they may start giving their contribution in this sense from the first half of the next decade onwards, as described in one of the following paragraphs.

Two different growth scenarios were developed on the following assumptions:

Scenario I: current economic trend, use of mature production technologies and price of crude oil at source of 250 US $/bbl in 2030 (roughly three times higher than the average price in 2010, which was 80 US $/bbl, or € 400-420/tonne);

Scenario II: economic trend driven by firm environmental policies, use of mature and advanced production technologies and price of crude oil at source of 300 US $/bbl in 2030 (roughly four times higher than that in 2010).

5.2) Growth forecasts 2010-2030

Based on the assumptions cited above, the growth estimations under Scenarios I and II, with steps at Dec. 2012-2015-2020-2025, are those shown in Table 1 and Figures 3/1-3/2 for power generation, and in Table 2 and Figures 4/1-4/2 for overall direct uses, including heat pumps.

6. CONTRIBUTION OF *UNCONVENTIONAL GEOTHERMAL SYSTEMS* TO POWER GENERATION UP TO 2030

We have already pointed out that *unconventional geothermal systems* are still far from being mature for commercial production of electric energy. Therefore, the figures of capacity installed and electricity produced shown in Table 1 and Figs. 3/1-3/2 up to the year 2020, are solely based on harnessing hot fluids from high and moderate temperature hydrothermal systems.

However, a robust R&D project specifically focused on development of *unconventional geothermal systems* should be

Table 1: Forecast development of geothermal power generation in Italy by 2030, with oil savings and avoided CO_2 emissions

Year		*2010*	*2012*	*2015*	*2020*	*2025*	*2030*
SCENARIO I							
Installed capacity	*(MW_e)*	882.5	882.5	940	1080	1250	1500
Gross generation	*(TWh/y)*	5.34	5.6	6.0	6.9	8.0	9.4
Oil saved	*(kTOE/y)*	1020	1070	1140	1310	1520	1790
Avoided CO_2 emissions	*(kTonnes/y)*	3200	3360	3600	4140	4800	5700
SCENARIO II							
Installed capacity	*(MW_e)*	882.5	882.5	950	1150	1500	2000
Gross generation	*(TWh/y)*	5.34	5.6	6.1	7.3	9.5	12.0
Oil saved	*(kTOE/y)*	1020	1070	1160	1390	1790	2280
Avoided CO_2 emissions	*(kTonnes/y)*	3200	3360	3660	4380	5640	7200

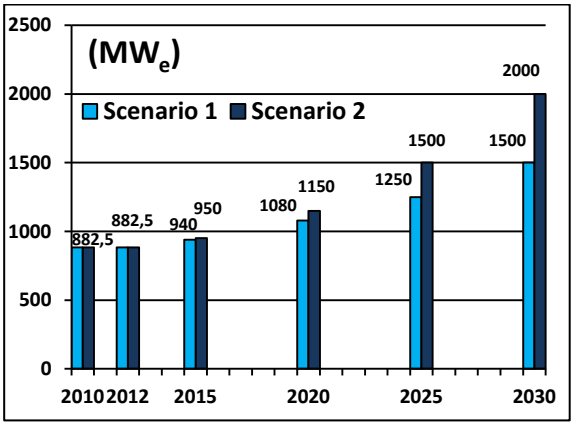

Fig.3/1: 2010-2030 development of installed capacity under Scenarios I and II

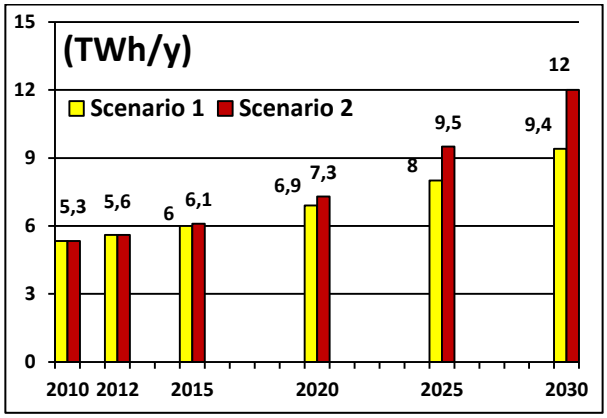

Fig.3/2: 2010 - 2030 development of power generation under Scenarios I and II

Table 2: Forecast development of direct uses in Italy by 2030 (including GSHP) with oil savings and avoided CO_2 emissions

Year		*2010*	*2012*	*2015*	*2020*	*2025*	*2030*
SCENARIO I							
Installed capacity	*(MWt)*	1000	1190	1560	2510	4200	7400
Gross production	*(TJ/y)*	12,600	14,430	17,930	26,380	40,500	65,200
Oil saved	*(kTOE/y)*	300	340	430	630	970	1560
Avoided CO_2 emissions	*(kTonnes/y)*	800	910	1120	1640	2520	4060
SCENARIO II							
Installed capacity	*(MWt)*	1000	1210	1630	2750	4800	8800
Gross production	*(TJ/y)*	12,600	14,700	19,040	30,660	51,700	90,000
Oil saved	*(kTOE/y)*	300	350	460	740	1240	2160
Avoided CO_2 emissions	*(kTonnes/y)*	800	910	1200	1920	3220	5620

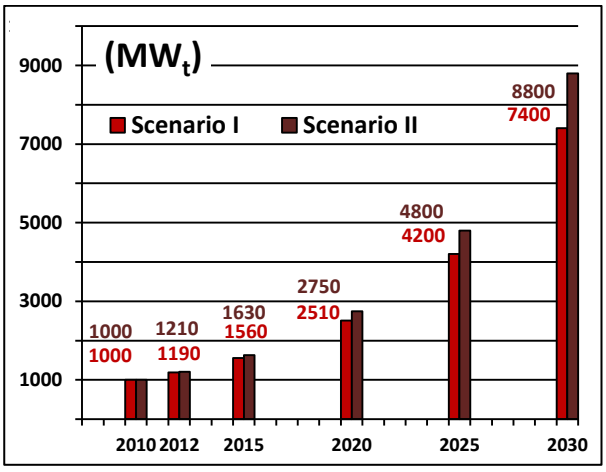

Fig.4/1: 2010-2030 growth of installed capacity of total direct uses including heat pumps under Scenarios I and II

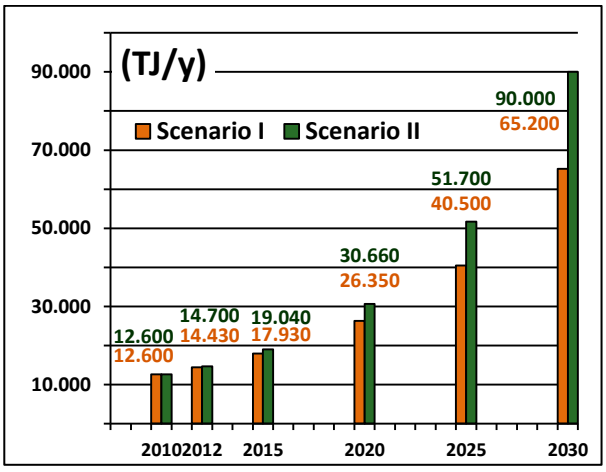

Fig.4/2: 2010-2030 growth of heat produced by total direct uses including heat under Scenarios I and II

started before 2015 aimed at preparing the technical ground necessary to assess their commercial viability for power generation under the specific geological conditions of Italy.

The ideas underlying such project are described in another paper presented at this Congress by (Cataldi et al. 2013).
Therefore, provided that this project is successfully completed within the first years of the next decade, in our projections of geothermal power generation in Italy by 2030, we have hypothesized that *unconventional geothermal systems* will gradually increase their contribution to the Italian geothermal electricity till reaching 12-15% of the total under Scenario I and 20-25% under Scenario II by 2030.

7. ENVISAGED REGIONAL DISTRIBUTION OF POWER GENERATION

Geothermal power generation in Italy has occurred till now only in the Larderello and Mt. Amiata regions in Tuscany. For the future, we envisage that such generation will still come from Tuscany alone until the end of 2015; afterwards, we expect that it will start coming also from other Italian Regions, among which Campania, Latium, Sardinia and Sicily are the most probable ones (Table 3).

Tuscany, however, with a share of at least 75% in 2030 according to Scenario II, will remain the dominant region in geothermal generation well beyond 2030 (Figs. 5/1 and 5/2).

Table 3: Forecast regional distribution of geothermal power in Italy by 2030

Regional distribution	*Capacity installed*		*Electricity produced*	
	MWe	*% of total*	*TWh/y*	*% of total*
SCENARIO I				
Tuscany	1200	80	7.7	82
Other Regions	300	20	1.7	18
TOTAL	**1500**	**100**	**9.4**	**100**
SCENARIO II				
Tuscany	1500	75	9	75
Other Regions	500	25	3	25
TOTAL	**100**	**100**	**12**	**100**

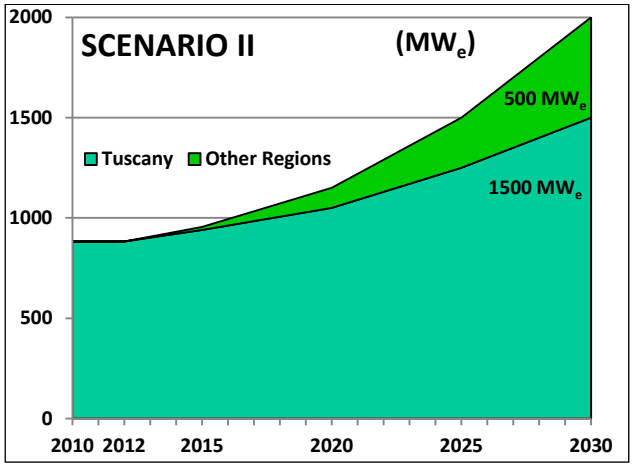

Fig.5/1:Forecast distribution 2010-2030 of installed capacity in Tuscany and other Italian Regions under Scenario II

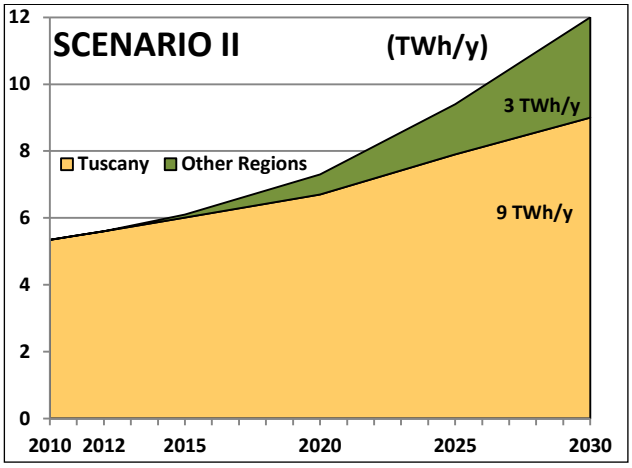

Fig.5/2: Forecast distribution 2010-2030 of electric energy in Tuscany and other Italian Regions under Scenario II

8. CONTRIBUTION OF GEOTHERMAL HEAT PUMPS TO TOTAL DIRECT USES

The growth of heat pumps from Dec. 2005 to Dec. 2010 was as follows: 215 MW_t capacity, with 850 TJ/y net energy produced in 2005, and 500 MW_t capacity with 1700 TJ/y net energy produced in 2010. These figures compare with the following totals of direct uses: 650 MW_t with 8200 TJ/y in 2005, and 1000 MW_t with 12,600 TJ/y in 2010.
The comparison shows that the contribution of heat pumps to total direct uses in Italy passed from ~ 33 % (215/650 MW_t) in 2005 to 50 % (500/1000 MW_t) in 2010 in terms of installed capacity, and from ~ 10.5% (850/8200 TJ/y) in 2005 to 13.5% (1700/12,600 TJ/y) in 2010 in terms of energy produced.

It is patent from the above that, due to the lower utilization time, and also because of other typically Italian factors, the energy produced by GHP is (just as for capacity installed) much less profitable than the energy produced from hot fluids directly. However, yet with higher costs, GHP are the only way to intensify the extraction of terrestrial heat from shallow rocks, soils, and low-temperature fluids. Therefore, they can play a significant role in the development of direct uses, especially for air conditioning.

The above figures also infer that, in the 2006-2010, the installed capacity of geothermal heat pumps in Italy grew at an average rate of 18.4 %/y. According to UGI, this high rate is attributable more to the initial rush of the market towards a new technology (which started to take root in Italy only in the last few years) than to a steady growth of demand; hence, the value of 18.4%/y is unlikely to continue for long periods of time. As a consequence, in our estimates till 2030, we have assumed that the installed capacity of GHP will grow at a rate in the range 10-12%/year under Scenario I and 11-13 %/year under Scenario II. The same can be said for the net energy produced by geothermal heat pumps, which recorded an exceptional growth rate of almost 15%/year in the 2006-2010 period. Thus, to estimate the net energy which may be produced by heat pumps till 2030, we assumed more conservative annual growth rates: 8-11% for Scenario I, and 10-13 for Scenario II. On these assumptions, starting from Dec. 2010, the envisaged development of GHP in Italy till 2030 is that shown in Table 4.

Table 4: Forecast growth of geothermal heat pumps in Italy 2010-2030: installed capacity and heat produced, with the relevant advantages in terms of oil-equivalent and avoided CO_2 emissions

Year		*2010*	*2012*	*2015*	*2020*	*2025*	*2030*
SCENARIO I							
Installed capacity	*(MWt)*	500	600	810	1.360	2.300	4.000
Net production	*(TJ/y)*	1700	1980	2530	3890	6300	10,600
Oil saved	*(kTOE/y)*	40	50	60	90	150	250
Avoided CO_2 emissions	*(kTonnes/y)*	100	130	160	240	390	650
SCENARIO II							
Installed capacity	*(MWt)*	500	620	860	1520	2700	5000
Net production	*(TJ/y)*	1700	2060	2780	4680	8200	15,000
Oil saved	*(kTOE/y)*	40	50	70	110	200	360
Avoided CO_2 emissions	*(kTonnes/y)*	100	130	180	290	520	940

By comparing the figures of installed capacity and energy produced, shown in Table, 4 with the similar figures shown in Table 2 for total direct uses, one can note the different contribution that heat pumps can give to the total, depending on whether we refer to installed capacity or heat production. The difference can be seen in Figs. 6/1-6/2 for Scenario II only. Each histogram, in fact, displays the total envisaged development of direct uses divided in two parts, in order to highlight the fraction of capacity (Fig. 6/1), or of energy (Fig. 6/2), that can be obtained with and without the use of heat pumps.

These figures confirm that the energy producible by heat pumps requires a high installed capacity; thus, it less profitable than the energy produced directly from hot natural fluids.

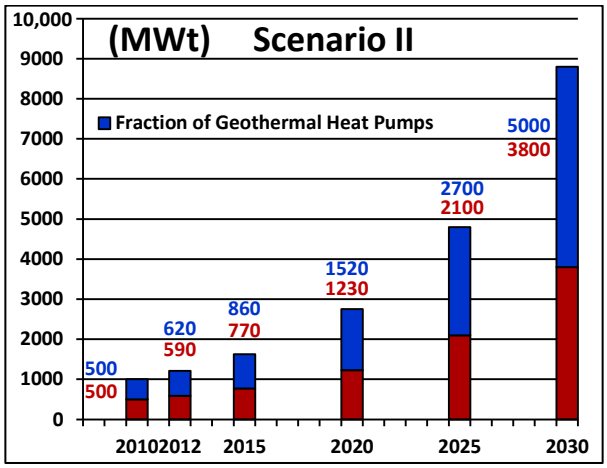

Fig. 6/1: Envisaged growth 2010-2030 of total capacity installable for direct uses under Scenario II, broken down into two parts: with and without heat pumps

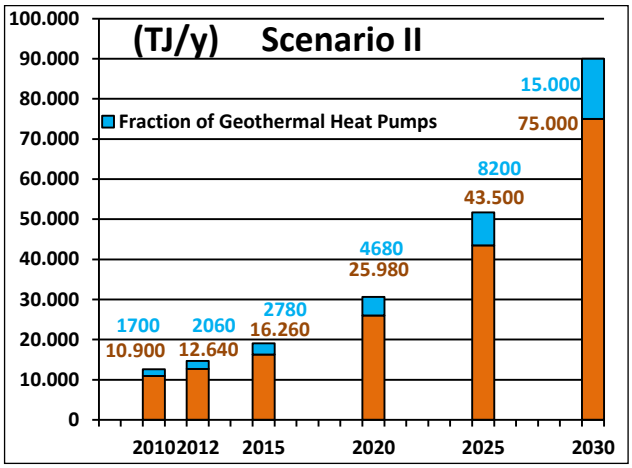

Fig. 6/2: Envisaged growth 2010-2030 of energy from direct uses under Scenario II, broken down into two parts: with and without heat pumps

9. ENVISAGED GROWTH OF THE DIFFERENT TYPES OF DIRECT USES

To better analyze the overall development of direct uses till 2030, direct uses were divided into five sectors of application, namely: 1) space heating & cooling; 2) thermal balneology; 3) agricultural uses (greenhousing and other); 4) fisheries; and 5) industrial processes and other minor uses.

The envisaged growth of these sectors is given in Table 5 for Scenario I and Table 6 for Scenario II.

Table 5: Hypothesized development 2010-2030 of the different sectors of direct uses under Scenario I

Year	*2010*		*2012*		*2015*		*2020*		*2025*		*2030*	
	TJ/y	*%*	*TJ/y*	*%*	*TJ/a*	*%*	*TJ/y*	*%*	*TJ/y*	*%*	*TJ/y*	*%*
Heating and cooling	*4750*	*38*	*5750*	*40*	*7700*	*43*	*12,650*	*48*	*21,850*	*54*	*39,100*	*60*
Thermal balneology	*4200*	*33*	*4450*	*31*	*4500*	*25*	*5300*	*20*	*6100*	*15*	*6500*	*10*
Agricultural uses (greenhousing and other)	*1500*	*12*	*1900*	*13*	*2500*	*14*	*3700*	*14*	*5650*	*14*	*9800*	*15*
Fisheries	*1800*	*14*	*1900*	*13*	*2350*	*13*	*3150*	*12*	*4050*	*10*	*4550*	*7*
Industrial processes and other minor uses	*350*	*3*	*430*	*3*	*880*	*5*	*1580*	*6*	*2850*	*7*	*5250*	*8*
Total heat	***12,600***	***100***	***14,430***	***100***	***17,930***	***100***	***26,380***	***100***	***40,500***	***100***	***65,200***	***100***
Total capacity, *MWt* *(of which heat pumps)*	***1000 (500)***		***1190 (600)***		***1560 (810)***		***2510 (1360)***		***4200 (2300)***		***7400 (4000)***	

Table 6: Hypothesized development 2010-2030 of the different sectors of direct uses under Scenario II

Year	*2010*		*2012*		*2015*		*2020*		*2025*		*2030*	
	TJ/y	*%*	*TJ/y*	*%*	*TJ/y*	*%*	*TJ/y*	*%*	*TJ/y*	*%*	*TJ/y*	*%*
Heating and cooling	*4750*	*38*	*6000*	*41*	*8400*	*44*	*15,000*	*49*	*28,400*	*55*	*56,700*	*63*
Thermal balneology	*4200*	*33*	*4450*	*30*	*4600*	*24*	*5500*	*18*	*6700*	*13*	*7200*	*8*
Agricultural uses (greenhousing & other)	*1500*	*12*	*1900*	*13*	*2650*	*14*	*4300*	*14*	*7250*	*14*	*12,600*	*14*
Fisheries	*1800*	*14*	*1900*	*13*	*2450*	*13*	*3700*	*12*	*5200*	*10*	*5400*	*6*
Industrial processes And other minor uses	*350*	*3*	*450*	*3*	*940*	*5*	*2160*	*7*	*4150*	*8*	*8100*	*9*
Total heat	***12,600***	***100***	***14,700***	***100***	***19,040***	***100***	***30,660***	***100***	***51,700***	***100***	***90,000***	***100***
Total capacity, MW_t *(of which heat pumps)*	***1000 (500)***		***1210 (620)***		***1630 (860)***		***2750 (1520)***		***4800 (2700)***		***8800 (5000)***	

Tables 5-6 show that the sector with far higher prospects of growth is space heating and cooling, which can attain a share of 60% of the total for Scenario I and of 63% for Scenario II by 2030.

Two other sectors with very good prospects, with rising shares of the total, are agricultural uses and industrial processes plus minor uses; whereas, thermal balneology and fish farming, yet growing in absolute terms, are likely to have a decreasing share.

Finally, the last lines of Tables 5 and 6 clearly show that, thanks above all to the notable growth of space heating and cooling, the total capacity of direct uses is expected to increase in absolute terms in the 2010-2030 period by over 7 times under Scenario I and by nearly 9 times under Scenario II.

10. SUMMARY OF FORECASTS AND REMARKS

Table 7 leads to the following values referred to energy produced:

- for power generation: growth rates in the range of 2-4%/year up to 2020 and of 2.5-6%/year from 2021 to 2030. They are notable annual growth rates, i.e. 2-4 times higher than those observed in the last 20 years in Italy and also significantly higher than the average annual growth rates recorded in the world in the same period. Therefore, compared to 2010 (5.34 TWh/y), geothermal generation in Italy is expected to rise in 2030 to: 9.4 TWh/year under Scenario I and 12 TWh/year under Scenario II. This means an approximate doubling of the generation of Dec. 2010 in 20 years;

- for direct uses *(including heat pumps)*: growth rates of 7-10%/year till 2020 and of 8-12%/year from 2021 to 2030. At these remarkable growth rates, direct uses will reach values of 65,200 TJ/y under Scenario I and 90,000 TJ/year under Scenario II by Dec. 2030; therefore, they will increase 5-7 times more than the total geothermal heat (12,600 TJ/year) used in 2010. The above emphasizes the difference between the envisaged increase of direct uses (5-7 times) and the one of power generation (about 2 times) in the 20-year period 2010-2030.

11. MEASURES NECESSARY TO ATTAIN THE TARGETS ENVISAGED

The Directives issued in the last few years by the European Commission in the field of renewable energy sources, especially Directive 2009/28/EC, represented the basis to enact legal provisions concerning renewables in general and geothermal energy in particular. Among those of special interest for the latter source, worthy of mention are: *i)* Law Decree 22/2010; *ii)* the National Action Plan (July 2010); *iii)* Law Decree 28/2011; and ***iv)*** UNMIG circular on authorization procedures for installation of pilot geothermal power plants (July 2011).

All these provisions represent useful tools to start launching (in certain cases) or relaunching (in other cases), the development of the Earth's heat in Italy. But, in our opinion, they are just a first step to reach the targets described in the previous chapter. Further actions to be taken by the Italian government and by the institutions involved in energy matters to foster the systematic development of geothermal heat can be divided into the following two main groups.

11.1) Measures at the national and institutional level

- strong environmental policies by the government, energy institutions, and political parties;
- a new National Energy Plan (NEP) specifying the contribution that each renewable energy source (RES) could give to total energy demand till 2030, with 5-by-5-year steps;
- R&D projects targeted at all RES to evaluate their potential and actual possibility of development in relation to the different conditions of social acceptability;
- enactment of a specific national law for geothermal energy forming a set of "guidelines" in this field for all Italian Regions;
- adequate and long-lasting incentives for the Earth's heat: the only energy source that is constant in time, environmentally benign and available everywhere especially for direct uses;
- implementation of a special R&D project aimed at preparing the technical groundwork for developing *Unconventional Geothermal Systems* under the particular geological conditions of Italy, starting before 2015 and ending in the first years of the next decade;
- public awareness campaigns about geothermal energy, including the economic and environmental benefits which can be reaped from its large-scale deployment, especially for direct uses.

11.2) Measures at the regional and local level

- energy plan in each Italian Region, with quantitative targets for each RES. For the Earth's heat, in particular, the target of each main development sector should be set;
- enactment of laws and rules for each sector of geothermal energy, with special regard to direct uses, taking into account the different situations of local development;
- assessment of the main energy consumption sectors (transport, building, industry, agriculture, etc.), with evaluation of heat demand in the medium and long term;
- comparative market studies on demand for low-temperature heat;
- quantification of CO_2 emitted by different energy sources for air conditioning of buildings;
- promotion by Regions, Provinces and Municipalities of the largest possible use of the RES for heating/cooling of buildings, especially public ones (hospitals, barracks, theaters, schools, etc.) and in all new large buildings (supermarkets, roofed stadia, skyscrapers, etc.) ;
- incentives for retrofits of old heating systems;
- training of designers, installers, maintenance operators on thermal plants supplied by RES, with particular reference to plants supplied by geothermal heat pumps;
- campaigns in school to raise awareness of the Earth's heat and of its environmental and economic advantages with a view to widely disseminating its systematic use.

Tab. 7:Total development of geothermal energy 2010-2030: power generation + direct uses

Year	*2010*			*2020*			*2030*		
SCENARIO I									
Power generation	882.5 *MW_e*	5.34 *TWh/y*	1020 *kTOE/y*	1080 *MW_e*	6.9 *TWh/y*	1310 *kTOE/y*	1500 *MW_e*	9.4 *TWh/y*	1860 *kTOE/y*
Direct uses *(including heat pumps)*	1000 *MW_t*	12,600 *TJ/y*	300 *kTOE/y*	2510 *MW_t*	26,350 *TJ/y*	630 *kTOE/y*	7400 *MW_t*	65,200 *TJ/y*	1560 *kTOE/a*
Total geothermal	-	-	**1.320 *kTOE/y***	-	-	**1940 *kTOE/y***	-	-	**3420 *kTOE/y***
Geothermal vs. total energy consumption in Italy	-	-	**~ 0.71(*) *%***	-	-	**~ 1 (*) *%***	-	-	**~ 1.5 (*) *%***
Avoided CO_2 emissions by total geothermal	-	-	**4000 *kTonne/y***	-	-	**5780 *kTonne/y***	-	-	**9760 *kTonne/y***
SCENARIO II									
Power generation	882.5 *MW_e*	5.34 *TWh/y*	1020 *kTOE/y*	1150 *MW_e*	7.3 *TWh/y*	1390 *kTOE/y*	2.000 *MW_e*	12.0 *TWh/y*	2280 *kTOE/y*
Direct uses *(including heat pumps)*	1000 *MW_t*	12,600 *TJ/y*	300 *kTOE/y*	2750 *MW_t*	30,660 *TJ/y*	740 *kTOE/y*	8800 *MW_t*	90,000 *TJ/y*	2160 *kTOE/y*
Total geothermal	-	-	**1320 *kTOE/y***	-	-	**2130 *kTOE/y***	-	-	**4440 *kTOE/y***
Geothermal vs. total energy consumption in Italy	-	-	**~ 0.71 (*) *%***	-	-	**~ 1.1 (*) *%***	-	-	**~ 1.9 (*) *%***
Avoided CO_2 emissions by total geothermal	-	-	**4000 *kTonne/y***	-	-	**6300 *kTonne/y***	-	-	**12,820 *kTonne/y***

(*) *Percentages referred to 185 MTOE for 2010 and to 200 and 230 MTOE hypothesized for 2020 and 2030, respectively*.

12. EXPECTED BENEFITS

The benefits expected from the targets described in a previous chapter can be expressed (separately for Scenarios I and II) by the figures given in Table 8 for the technical-economic and environmental benefits, and for the social and scientific benefits.

Tab.8: Summary of benefits expected from geothermal development in Italy by 2020 and 2030 under Scenarios I and II

	SCENARIO I				***SCENARIO II***			
	2020		***2030***		***2020***		***2030***	
i) Technical-economic and environmental benefits								
Power generation	6.9 TWh/y	*1310 kTOE/y*	9.4 TWh/y	*1860 kTOE/y*	7.3 TWh/y	*1390 kTOE/y*	12.0 TWh/y	*2280 kTOE/y*
Direct uses *(including GSHPs)*	26,380 TJ/y	*630 kTOE/y*	65,200 TJ/y	*1560 kTOE/y*	30,660 TJ/y	*740 kTOE/y*	90,000 TJ/y	*2160 kTOE/y*
Total geothermal… …. *(kTOE/y)*	*1940*		*3420*		*2130*		*4440*	
Geothermal vs. total energy consumption in Italy…….. *(%)*	*~ 1*		*~ 1.5*		*~ 1.1*		*~ 1.9*	
Avoided CO_2 emissions by total geothermal ..... *(kTonnes/y)*	*5780*		*9760*		*6300*		*12,820*	
ii) Social and scientific benefits								
Jobs *(graduates, technicians, workers, etc.) (no.)*	*50,000*		*100,000*		*100,000*		*200,000*	
Drilling, plants, etc. …… …*(M€)*	*300*		*1200*		*500*		*2000*	
R & D activities …… … *(M€)*	*100*		*200*		*200*		*400*	

With reference to 2030 and Scenarios I and II, Table 8 shows that total development of geothermal energy is expected to:
- range between 3.4 and 4.4 MTOE/year;
- have a share of 1.5-2 % of total energy consumption in Italy;
- displace CO_2 emissions in the range of 10-13 million tonnes/year;
- create 100,000 to 200,000 new jobs per year;
- encourage investments of 1.2-2 billion Euro; and
- stimulate R&D activities for 200-400 million Euro.

Some of the above figures may seem small percentage-wise; but they are not small in absolute terms if one considers that Italy is an industrialized country with a limited surface area, poor of indigenous energy sources and high energy-intensive.

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