ITALIAN GEOTHERMAL NEW FRONTIERS

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ABSTRACT

The expression "Italian geothermal new frontiers" includes the exploitation of the low and high enthalpy resources Other than the traditional systems.
Some of these resources will be available only in the mid and long-term future; other ones are ready now.
The first category includes essentially the exploitation of "hot dry rocks". The second concerns the exploitation Of low and very low temperature resources originating from: recovery from exhausted oil and gas wells; recovery of polluted Water wells; exploitation of aqueduct waters; exploitation Of shallow ground heat.
This report gives a general rewiew of the aforesaid topics.

1. INTRODUCTION

In Italy, the exploitation of low and high geothermal energy is less that what is possible. though the country is rich enough in these resources.

Owing to many factors like: inadequate local and governmental rules, natural gas commercial competition. insufficient promotion and economic incentives, in the last few years there has been practically no development in this field.

Time is ripe for a revision of the regulations both to improve the traditional geothermal activity and to Stimulate the development Of the unconventional geothermal resources theoretically available but not yet utilized. We refer in particular to:

1) very low temperature resources in the subsoil or in the soil exploitable by heat pumps;
2) the recovery of the thermal energy from polluted water wells, from exhausted oil and gas wells and from flooded and abandoned deep mines;
3) the heat exploitation of aqueduct and sawage waters;
4) HDR systems.

The specific laws and national geothermal resources inventory should be improved. The purpose of the paper is to call the attention of central and local authorities and public and private Operators to these problems.

2. AQUIFERS IN THE ITALIAN SUBSOIL

We first summarize the hydro-geothermal peculiarities of the Italian subsoil. The Alpine and Apennine regions are characterized by:

1) fresh, phreatic and vadose waters, sometime of karst origin. with metheoric supply;
2) the ascent towards the surface of warm deep waters, by faults or convection. Generally, the temperature originates from "heat gradient", but sometimes from exothermic reactions.
3) mixing of vadose waters and/or thermal waters with "fossil". salt waters or infiltrated sea waters.

In the Po Valley basin and along the Apennine fore deep basin, from the Alps to Sicily, superficial fresh Waters are included in clastic Tertiary sediments or/and in the underlying carbonate section from few meters to about 1000 m depth. Moreover, in the Po Valley it is possible to find fresh artesian waters (with feeding from the Alps) in carbonate aquifers up to 4000 m deep (see RODIGO well. Mantua area) and salty-sulfate waters (with feeding from the Apennines) (see CASAGLIA wells. near Ferrara). Pressure values are hydrostatic. The temperatures are those of the heat gradient (medium value: about 20°C/1000 m).

Deeper Waters are salty, fossil and associated with hydrocarbon reservoirs. Below 3500 m the aquifers may be geopressured. TRECATE wells [northern Italy) reach carbonate reservoirs 5000-7000 m deep. The temperature is around 150-210°C. The pressure values reach 350-1150 bar, with overpressures of 300-400 bar, owing to the weight of the upper and lateral sediments and/or tectonic actions.

3. AQUEDUCT WATERS

Aqueduct waters present uniform temperatures, similar to the annual local ambient average temperature, that is 7-20°C (13-17°C in the Po Valley) depending on the latitude and altitude of the site and depth of the originating aquifer.
The thermal exploitation Of these resources can take place by heat exchangers (Without drawing of fluids). These resources can be exploited by cooling the fluids up to 5-7°C. In the water tanks and in the aqueducts, Water will reach again its original temperature, thus with no problems for the

consumers. Such exploitation are very interesting. because of the considerable **amount** of fluids, the constant temperature and the absence of mining **works** and risks.

4. ABANDONED WATER WELLS

Today, many shallow Water wells (10-50 m deep) are abandoned because of pollution. Their temperature is similar to the local annual average temperature. These fluids **can** be exploited by heat pumps and then reinjected into the aquifers. When conditions **are** suitable, it is possible to use also borehole heat exchangers without extracting water. Early applications are the heating plants installed in **some** buildings in Milan and Zurich during the years 1939–1942 (heat pump and water at **13°C**). Nowadays, **such** plants are very numerous (Northern France, Switzerland, USA, etc.)

5. MINES AND TUNNELS

In Italy, most metal, salt, sulphur and coal mines have been abandoned, because they are uneconomic. They are mainly situated in the Alps, in Tuscany, Sicily and Sardinia.

As done in Canada, these mines **can** be utilized exploiting geothermal heat of flood waters (meteoric waters from surface or thermal waters from deep levels). Besides mines. we must also consider railway, motorway and hydroelectric tunnels. Deep waters can be extracted through heat-insulated pipes utilizing wells and galleries. Tunnel waters **can** be utilized below mini-hydroelectric penstocks. In this **case**, the water temperature may be higher by 1-1.5°C **on** account of the lover altitude of the discharge and the friction in the turbine. At present, two projects of this kind ***are*** being considered: the first. relates to the **Brosso** mine (Ivrea area, Piedmont); the second one regards **a** marble quarry in the Brenner region (Alto Adige) with large flow of **14-17°C** water. In the Mont Blanc tunnel, **some** thermal waters, with a temperature of 56°C have been found.

6. RECOVERY OF GEOTHERMAL ENERGY FROM HYDROCARBON WELLS

The first big projects for low enthalpy geothermal **energy** exploitation (particularly for space heating plants) were born after the discovery Of **warm** waters in hydrocarbon exploratory wells. This proves how important hydrocarbon exploration was and is still for **low** enthalpy geothermal prospecting. Actually it offers **a** double benefit:

1) the possibility of obtaining **a** knowledge of the buried aquifer bodies;
2) the possibility of exploiting. for geothermal purposes, the hydrocarbon wells, which would not be used otherwise;

Countries like Hungary and Romania (but also Italy. **France,** Poland, etc.) have shorn a considerable interest in using hydrocarbon exploration data and **wells** for geothermal activities.

Moreover, an equally important contribution can originate from exhausted oil or gas wells which are no more utilized. As **a** matter of fact. there **are** **many** marginal hydrocarbon fields producing water (at various temperatures) mixed with poor quantity of oil **or** gas. In this **case**, the residual natural gas could represent an additional **energy** source.

When considering exhausted field, **a** very important aspect is the permeability of the reservoir. now considered as an aquifer body. The problem becomes **even more** important in presence of clastic reservoirs (like in the Po Valley). Here, the permeability values of the reservoir rock, sufficient **as** far **as** hydrocarbons are concerned, may be **on** the contrary **poor** for water exploitation. It follows that many depleted oil and gas wells are not suitable for supporting an economic geothermal project.

The following factors **are** also very important:
1) Location - The site can represent **a** limitative aspect when the utilizations concern space heating. because. in this **case.** the producing well has to be not very far from the user. When the appliations are in the agricultural field (greenhouses, aquaculture, etc.) the plant **can** be erected on the spot.
2) Productivity - As said before, the water flow-rate from the well might be unsufficient for **a** profitable use (owing to the low reservoir permeability). In this **case** we one should evaluate the possibility of increasing production by stimulating the reservoir (by fracturing. acidizing, etc.).
3) Temperature - This parameter depends on the utilization of the geothermal fluid which is possible in the region where the well is located, also considering the possible **use** of heat pumps.
4) Water Salinity – This is a critical element for fluid utilization. Fresh water. in fact, can sharply reduce the cost of **operations** (see Vicenza project).

For what concerns Italy, according to published information, **over** 2600 hydrocarbon deep wells have been drilled on land. About 50% of them are producers and are located in 60 fields mainly gas-bearing.

Most of these wells are within the depth of 4000 m (max. temp. = **110°C**). More than 50 of them **are** deeper (max. 7300 m, max. temp. 210°C). Even if, **as** said before, there are restrictive factors reducing considerably the number of geothermically interesting wells, their entity remains sizable. This is an interesting Sector for the development of low enthalpy geothermal activities.
A critical factor relative to the utilization of hydrocarbon wells is the relationship between the original owner and the new operator especially for what **concerns** the availability of the well prior to its abandonment.

7. GEOTHERMAL HEAT PUMPS (GHP)

Geothermal heat pumps are of two main types. **One,** the earth-coupled GHP, uses sealed horizontal or vertical pipes as heat exchangers through which water is circulated to transfer heat. The second type. the groundwater heat pump. extracts the heat

LOCATION MAP OF TYPICAL UNCONVENTIONAL GEOTHERMAL PROSPECTS

▲ ABANDONED MINES - ● GEOPRESSURED WELLS - ★ HDR POTENTIAL SYSTEMS

from water produced from a shallow well. There is also the possibility of extracting heat from the ground, transferred by building pillars. Heat production from low temperature heat pump-assisted systems is a quite promising field of geothermal energy use. This is due to the fact that the areas containing shallow aquifers are much more Widespread than the conventional geothermal basins, while ground heat is ubiquitous: moreover. the geologic risk involved in deeper geothermal resources is almost absent and investments substantially reduced.

This branch of geothermal energy utilization is one which is included in the most recent (1992) Energy Policy Act of the USA. The U.S. Department of Energy (US-DOE) is directed to encourage local governments to use geothermal heat pumps and to permit the use of available water for operating heat pumps. Geothermal heat pumps are seen by US utilities as a way to reduce peak demand of electricity. and as such, a heat producing system to be incentivated. Barriers to market entry are higher initial Costs than other heat pump systems, due to the investment for the ground loop installation and a Scarcity of integrated operators and dealers. A common problem to all heat pump systems is the price of electricity.

Notwithstanding the above constraints, geothermal heat pumps have seen a large development in the USA: almost 60,000 groundwater heat pumps and Over 90,000 ground-coupled systems were in existence in 1993. Groundwater heat pumps have also seen a substantial development in Germany, Sweden, France (where about 30.000 equivalent dwellings were connected to shallow aquifers in 1994). In Switzerland over 5000 space heating units using borehole heat exchangers connected to heat pumps have been installed: temperature involved range from 10 to 20°C. While most of the applications relate to single households, there are examples of small condominium systems (France), office buildings (with heating and cooling uses) in various countries and also of t o m district heating networks (Lund in Sweden with an installed capacity of 25 MWt).

Italy has seen few initiatives in this promising sector of geothermal energy use, whilst. as elsewhere in the world, the extent of the areas where Shallow low-temperature groundwater is available is much wider than the classical hotter geothermal areas. Ground heat is of course pervasive. One of the first steps to promote a significant use of the shallow heat resource should be an integrated assessment program involving both compilation of available information on resource coupled with heat load data, informing the public, and installing and testing some pilot schemes, on the model of the US-DOE program. Pricing of electricity and utilities cooperation will be critical.

8. HOT DRY ROCK (HDR)

The heat stored in the earth's interior can be extracted [partially and indirectly) by producing the underground aquifers warmed by the geothermal heat of the surrounding rocks or by artificially circulating a fluid in an expressly created fracture system (HDR technique). These last are the resources that in the long term (beyond 2010) may allow a sizable increase in geothermal reserves. provided the presently existing technical problems are solved and the price of traditional fuels increases or due monetary weight is given to the beneficial effects on pollution of geothermal energy.

Mining of rock heat in the described way is in the experimental Stage in many parts of the world. Many nations are making an effort in HDR (mainly the USA. Japan, UK. France and Germany) with local government, EC and IEA Support and funding.

HDR R&D is multidisciplinary and requires the cooperation of industry which has the know-how in some key sectors of this research and is better equipped to field-test the results of laboratory and theoretical investigations, possibly on suitable abandoned geothermal wells. Industry could benefit, in return both in the specific geothermal field and in oil operations where targets are getting deeper and thus hotter and fractured rocks are often the reservoir. While much Of the R&D in HDR has been undertaken in moderate gradient areas (which are certainly predominant compared to the ones with anomalous temperatures) it is recognized that only generation of very hot fluids from an HDR system can be economical in a reasonable time-frame. Exploiting a moderate gradient area would necessitate the drilling and completion of very deep wells, thus increasing technical difficulties and costs.

SO it is essential that experimentation be carried out in high-gradient areas. Such an approach is being currently followed in Japan and is in the advanced planning Stage in the USA.

In Europe. Italy, together with Greece and Turkey. is the country where large areas present an anomalously high gradient, verified by numerous wells. From the geothermal point of wiew, Italy can be divided in two main regions: the Western (Thyrrenian) hot sector; the Eastern (Adriatic) cold belt. All the high temperature geothermal fields are located in Tuscany (with one exception in Latium). Exploration in the Thyrrenian belt has evidenced the existence of three main anomalous zones: one in Tuscany and Latium, extending to Rome and possibly southwards over an area exceeding 10,000 km^2; another centered North and West of Naples (with a surface of 500 km^2); a third one in the Aeolian islands North of Sicily.

Several deep wells have been drilled in recent years in three zones, many Of them reaching very high temperatures at shallow depth, but evidencing the presence of tight formations. For instance. 420 to 460°C at 2000-4000 m depth in S.POMPEO-1 (Tuscany), LATERA-10 (Latium), S.VITO-1 (Campania) and ISOLA DI VULCANO-1 (Sicily) wells.

As example of such situation., favourable as sites for HDR experimentation, we can indicate the following wells:

- SABATINI SH-2 in Latium encountered between 1160 and 2499 m (T.D.) impermeable thermometamorphic rocks with a well bottom temperature of 290°C.
- LATERA-5, also in Latiwn. drilled a syenite intrusive body between 2070 and 2651 m (T.D.) with a well bottom temperature of 297°C.
- S.VITO-8D, located North of Naples in the Flegrei caldera. penetrated volcanics up to 2340 m followed by tight termometamorphic rocks to a total depth of 2868 m; temperature at 2650 m was 304°C.

Given the above described situation, Italy is particularly well-suited for pursuing an R&D effort on HDR energy.

Interest for Italy to be involved in such an activity was expressed in the 1988 National Energy Plan and an hypothetical working scheme was prepared but never enacted.

It is to be hoped that the continuing European interest in renewable energies. expressed in the Declaration of Madrid of March 1994 and in the attached Action Plan for Renevable Energy Sources in Europe, Will give life to an HDR effort in Italy.

9. GEOPRESSURED RESERVOIRS.

About fifty deep to very deep wells in the Po

Valley (max depth 7300 m, max temperature 210°C) including those drilled in the two oil fields of MALOSSA and THECATE have met high pressure **zones** mostly in Mesozoic carbonate.

Even if of theoretical interest, economic factors make it practically impossible to drill **new wells** expressly for developing geopressured hot fluids, while utilisation of the depleted hydrocarbon wells is not feasible because of the rapid decline in pressure consequence of the field exploitation.

10. CONCLUSIONS

In this report possible new directions to accompany conventional geothermal activities in Italy are described. **Of** particular interest is the low temperature resources exploitation by heat pumps, so widespread in other countries but neglected in Italy. Moreover, the Hot Dry Rock topic is particularly interesting in Italy **because** of the very high temperatures at small depth make this field very promising in a **large area**.

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