Geothermal Energy Use, Country Update for Italy

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ABSTRACT

This paper presents an overview on the development of geothermal energy applications in Italy for the year 2018 for both electricity generation and thermal uses. Geothermal power plants are located in Tuscany, in the two "historical" areas of Larderello-Travale and Mount Amiata. Thermal energy applications are widespread over the whole Italian territory. To date, Enel Green Power is the only geo-electricity producer in Italy. On 2016, with an installed capacity of 915.5 MW_e, the gross electricity generation reached about 6.3 billion kWh, which represented a new record of electricity produced from geothermal resource in Italy. At the end of 2018 no additional units were installed and the gross electricity generation was of about 6.1 billion kWh.

As far as thermal uses are concerned, at the end of 2017 the total installed capacity amounted to 1424 MW_{th}, with a corresponding heat energy use of 10915 TJ/y. The main share is held by the space heating sector (42% of the total energy, 52% of the overall installed capacity), followed by thermal balneology (32% in both values) and fish farming (18% and 9% namely). Agricultural applications, industrial processes and other minor uses together account for around 8% of the total geo-heat use. In the past 7 years the direct use of geothermal heat has registered a rise of 26% and 40% in terms of energy use and installed capacity respectively, with ground-source heat pumps (GSHPs) and district heating applications (DHs) being the most widespread technologies that have more than doubled their capacity since 2010.

1. INTRODUCTION

Geothermal resources are abundant in Italy, ranging from resources for shallow applications (mostly heat pump technology), through to medium (>90°C) to high (>150°C) temperature systems at depths accessible only by wells (usually within 3-4 km). High temperature systems tend to be in tectonically active regions either in volcanic and intrusive or fault-controlled systems (Santilano et al., 2015 and ref. therein).

Electricity from geothermal resources nowadays is produced in the Tuscany region, central Italy. Many direct applications of geothermal heat are also located in Tuscany, however thermal uses are widespread in the national territory, with district heating systems (DHs) mostly localised in the north and other direct uses and ground source heat pumps (GSHPs) distributing on a much larger territory.

The first part of this paper (sections 2-5) deals with geo-electricity production, describing current status, the development during the three-years period 2016-2018 and future perspectives with a particular focus on new power plants and drilling activities.

The second part (sections 5-9) illustrates the current status of thermal applications in Italy, and discuss their evolution in a 7-year period (2010-2017), 2017 being the most recent year for which data are available at the date of this report. The market and support measures are described in section 10, and discussion and conclusion in section 11.

Data are based on Enel Green Power database for electricity generation. Data regarding thermal applications are derived mainly from the Italian Energy Services Manager (GSE) publications, enriched by datasets and information of the two geothermal Associations (UGI and ANIGHP).

PART 1: GEOTHERMAL ELECTRICITY GENERATION

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2. THE ELECTRICITY MARKET IN ITALY AND ENEL GREEN POWER

In the year 2018 the electricity needs in Italy reached 321.91 billion kWh, with a domestic contribution of about 87.0%, while a relevant 13.0% was imported (preliminary data, not validated, from Terna 2018). The estimated electricity generation capacity and production data in Italy as of 2018 are summarized in Table A. As regards the 280.2 TWh of net domestic electricity generation, 66.0% comes from thermal, 17.6% from hydro and 16.4% from geothermal, wind and solar (Fig. 1). Although the contribution of geothermal electricity generation is only 2.0% of the whole Italian generation, it covers over 30% of the electricity needs in Tuscany, giving a substantial contribution to the green energy generation.

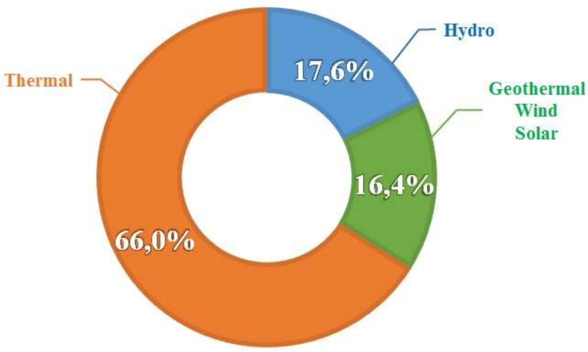

Figure 1: Electric domestic net generation in Italy (2018).

In 2018 the average market price of electricity was 6.191 Eurocent/kWh (GSE, 2019).

In 2018 the value of the GRIN tariff (Ex green certificates) for the plants that have access to this type of incentive was 9.9 Eurocent/kWh in addition to the average market price of electricity. To this value the specific reduction coefficients foreseen for the type of technology and the type of intervention carried out must be applied (GSE, 2018a). The 2016 FER Decree defined the new "Base Incentive Fee" for geothermal plants reduced by a percentage due to the auction reduction: 13.4 Eurocent/kWh (under 1 MW_e installed Capacity), 9.8 Eurocent/kWh (for plants between 1 MW_e and 5 MW_e) and 8.4 Eurocent/kWh (over 5 MW_e installed Capacity). All these tariffs are already inclusive of the average market price of electricity (Ministerial Decree D.M. 23/06/2016).

All recent official documents forecasting energy production from RES in Italy envisage a small growth for geothermal energy applications. The Italian Energy Strategy released in 2017 (MISE, 2017) predicts a rather limited increase of production for electricity, and declares the wish to establish a support scheme for geothermal innovative technologies demonstrating electrical power production with zero emissions. While a support scheme for zero emission or other innovative technologies has not been established yet, on January 2019 geothermal power plants were excluded from the possibility to participate in the bids for incentive schemes offered to RES power plants.

3. GEOTHERMAL POWER GENERATION: CURRENT STATUS AND DEVELOPMENT

The historical trend of electricity generation from geothermal resources in Italy is given in Fig. 2, where two different increase phases are shown: the first one in the period from 1930s to the mid 1970s, related to the development of the shallow carbonate reservoir, with well depths up to about 1000 m. The second one from the beginning of the 1980s up to now, when the fluid production has been increased thanks to the positive results of the deep drilling activity and to the artificial recharge of the depleted shallow reservoirs by means of the reinjection of water and condensed steam.

At present, all 34 of the country's geothermal power plants are managed by Enel Green Power (EGP), the Enel Group company that develops and manages energy generation from renewable sources at a global level, present in all the continents. EGP is a major global operator in the field of energy generation from renewable sources, with an annual production of 82 TWh, mainly from water, sun, wind and geothermal, avoiding million tons of CO_2 emissions per year.

In 2016 EGP experience in geothermal fields management allowed the gross electricity generation to reach about 6.3 billion kWh, which represented the new record of electricity produced from geothermal resource in Italy within nearly a century of operations. During the year 2018, with an installed capacity of 915.5 MW_e, the electricity gross generation was 6064 GWh. The complete list of the power plants in operation is given in Table B; taking into account the real operating conditions of the plants in the different areas (pressure, temperature, non- condensable gas content in the steam), the total running capacity (Reference Net Capacity) is 761.2 MW_e.

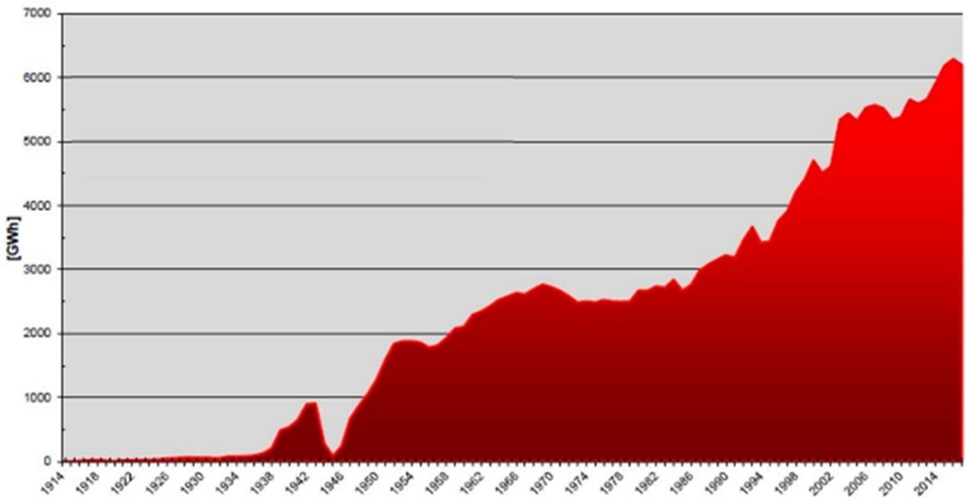

Figure 2: Historical trend of electricity generation from geothermal resources in Italy.

3.1 Plant for Hg and H_2S abatement (AMIS)

Enel developed and patented a proprietary technology, named "AMIS" (Abbattimento Mercurio e Idrogeno Solforato - mercury and hydrogen sulfide abatement). The AMIS system allows the removal of substances such as mercury and hydrogen sulfide present in the non-condensable gases of geothermal fluid. The process involves a stage of catalytic oxidation, by which the H_2S is selectively converted to SO_2. Thereafter, the SO_2 produced is absorbed in the water of the cooling circuit, through a packed column. Also the mercury, which is present in the geothermal fluid can be removed by adsorption on fixed beds of sorbents with specific yields of over 95% (Sabatelli et al., 2009).

As 2018, 34 AMIS groups are in operation, providing each power plant with this technology. In 2018, the averaged availability of AMIS plants (hours of operation vs hours of operation of the associated power plant) exceeded 90%.

4. GEOTHERMAL FIELDS UPDATE

All of the Italian geothermal fields in exploitation for electricity generation are located in Tuscany (Fig. 3): Larderello, Travale-Radicondoli, Bagnore and Piancastagnaio (the two latter being located in the Mount Amiata area).

All of the geothermal power plants managed by EGP are remotely controlled and operated from a Remote Control Station located in Larderello, where 12 people work in round the clock shifts (24/7), thus ensuring a continuous overseeing. In this way, every plant operating parameter can be monitored and analyzed and it is also possible to shut down and restart any unit from the Remote Station. This solution has allowed a better plant operation, at the same time dramatically reducing operating costs.

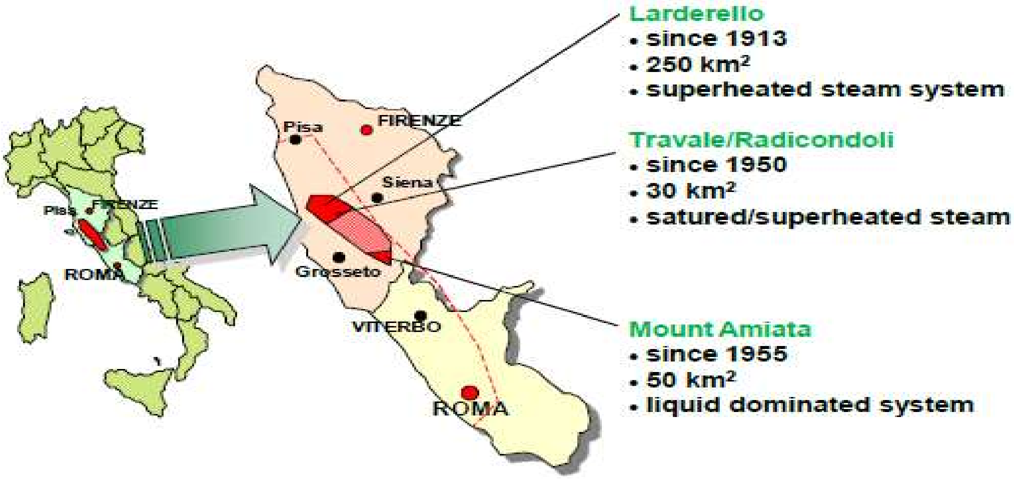

Figure 3: Location of the geothermal fields in Italy.

4.1 Enel Green Power activities in Tuscany

The activities carried out by EGP over the last three years have been concentrated mainly in Larderello and Travale-Radicondoli areas and were targeted at fields management optimization to reduce and contrast the natural decline. Serious acceptability problems from local communities have hindered further developments in the Mt. Amiata area, where the high potential deep reservoir could be further exploited.

4.1.1 Larderello

The explored area is about 250 km^2, where 200 wells produce superheated steam at pressure between 2 and 15 bars and temperature ranging from 150°C to 270°C. The non-condensable gas content ranges from 1 to 10% by weight. The installed capacity is 594.5 MW$_e$ as of December 2018, with 22 units in operation. The area of Larderello has been exploited since the beginning of the 1900s and resource sustainability is ensured through two main strategies for the management of the reservoir: reinjection and deep drilling. Since the late 1970s, the reinjection of the steam condensate back into the shallow carbonate reservoir formation has been highly beneficial, especially in the most depleted area (Valle Secolo) and made it possible to increase the reservoir pressure and, accordingly, the steam production (Cappetti et al., 1995). The deep exploration program showed the presence of permeable layers within the Metamorphic Basement, up to 3,000 – 4,000 m depth, with reservoir pressure and temperature increasing with depth up to 7 MPa and 350°C, respectively (Barelli et al., 1995, 2000; Bertini et al., 1995; Cameli et al., 2000; Bertani et al., 2005).

In 2018 EGP started the construction of Monterotondo-2 geothermal power plant for additional 20 MW$_e$ gross, on a new lease located SE of the traditional area, close to Lago Boracifero.

4.1.2 Travale-Radicondoli

The explored area covers approximately 50 km^2; 38 wells produce superheated steam at pressure ranging from 8 to 20 bars and temperature of 190-250°C. The non-condensable gas content is in the range of 5 – 6.5% by weight. The installed capacity is 200 MW$_e$ with 8 units in operation. The deep exploration, performed in previous years, showed also in this area the presence of permeable layers within the Metamorphic Basement, which resulted at the same depths and with the same reservoir temperature and pressure as in the Larderello area. Moreover, some of the deep wells (at depths of about 4000 m) showed the presence of productive layers also in the Granite underlying the Metamorphic Basement. It must be pointed out that the deep drilling activity proved that the two old and shallow fields of Larderello and Travale-Radicondoli represent the "outcropping" of a unique, wide and deep (3000-4000 m) geothermal system, with an extension of about 400 km^2. At a depth of about 3000 m, the same temperature and reservoir pressure was found (300-350°C and 6-7 MPa) both inside the field and in the marginal areas (Bertani et al., 2005).

The drilling activities have continued even in the last three years with 5 new production wells that have allowed to find new steam and reduce the natural decline of the field. To reduce the mining risk and to identify the main potential drilling targets, make-up wells are located on the basis of a joint accurate interpretation of the well data and seismic 3D surveys.

The intensive exploitation of the Travale-Radicondoli geothermal field caused a change in the thermodynamic properties of the fluid; the lowering of the pressure induced by the extraction of fluid determined an increasing overheating by heat mining process. Therefore, there is an ongoing testing for reinjection into the deep reservoir to investigate the possibility to reduce the field natural decline through the evaporation of water injected.

4.1.3 Mount Amiata

Two geothermal fields are located in this area: Bagnore and Piancastagnaio. They were discovered between the late 1950s and the early 1960s, with wells producing steam from the shallow carbonate reservoir. In the late 1970s, a deep exploration program was begun and the results were very successful in both of these fields, revealing the presence of fractured layers at depths ranging from 2500 to 4000 m inside the Metamorphic Basement underlying the shallow carbonate reservoir. This deep reservoir is liquid-dominated, with a pressure of around 200 bars and a temperature of 300-350°C at 3000 m depth (Bertini et al., 1995). The produced fluid is a two-phase mixture that is separated at wellhead at 20 bars; the non-condensable gas content in the steam ranges from 5 to 8% by weight.

As of December 2018, the total installed capacity is 121 MW$_e$, with 7 units on line.

4.1.4 New development leases

In 2018, following a surface exploration started some 5 years before, EGP was granted two new development leases, one in Larderello and one in Mount Amiata: Boccheggiano and Roccalbegna (Fig. 4).

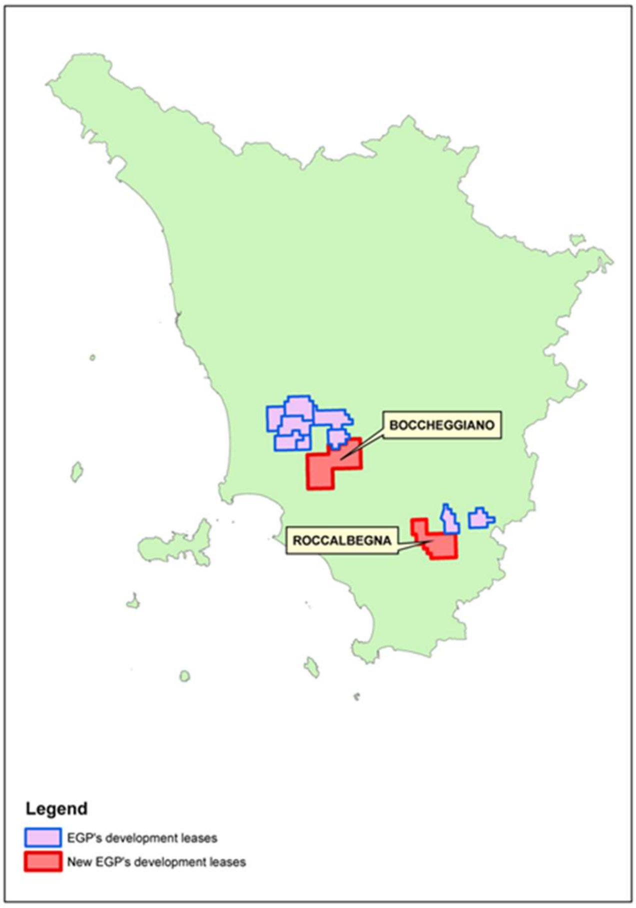

Figure 4: Location of the actual development leases of EGP; the new leases in red.

The necessary EIA documentation is now submitted to the local authorities in order to start activities for future well drillings and power plants development. The planned additional capacity for each area is 20 MW$_e$ gross.

4.1.5 Personnel and development

The number of professional personnel allocated to geothermal activities by EGP and the overall investments are shown in Table F. Table F provides also the figures estimated by GSE (2018b).

4.1.6 Drilling

In the period 2016 - 2018 a total of 27 geothermal wells were drilled in Italy, for a total drilled depth of 46.5 km. Fifteen are make-up wells drilled in Larderello (10) and Travale-Radicondoli (5) fields and they are relevant to the maintenance program to contrast natural decline of geothermal production. One new well is dedicated to the reinjection/injection program.

4.1.6.1 DESCRAMBLE project

Between 2015 and 2018 EGP coordinated and carried out the DESCRAMBLE project, an EU founded project under the H2020 framework aimed at drilling and testing new equipment in extremely high temperature and pressure conditions in continental-crust. Drilling was conducted in the Lago area, deepening an existing dry well: Venelle_2. The target was to reach the so called K-horizon in Larderello, where supercritical conditions (T>450°C and P>450 bar) were hypothesized. Before drilling new geophysical surveys (MT, VSP) and numerical modelling were conducted together with development of new drilling and measuring tools capable to resist such harsh predicted conditions. Final results and details on this project can be found in Baccarin et al. (2019).

PART 2: GEOTHERMAL THERMAL USES

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5. THE THERMAL MARKET IN ITALY FOR RENEWABLE ENERGIES

Following the official national reporting (GSE 2018b), the share of geothermal heat production, excluding geothermal heat pumps, in the total thermal production by Renewable Energy Sources (RES) is 1.3%. The vast majority of RES heat production is from solid waste (68%), followed by heat pumps (25.9%). Of the latter, only a very minor part is represented by GSHPs, about 0.07% in number of appliances and 0.62% in heat production (GSE, personal communication). In Italy most of the heat consumption from RES is for residential heat (38.2%) and services (36.4%), with only 3% dedicated to industrial uses. About 22% of RES heat production is lost in the transmission.

6. TERMINOLOGY, EVALUATION, METHODOLOGY, AND DATA ACCURACY

The data presented in this part have been produced using the same methodology presented and applied in previous Italian Country Updates, as established by UGI, the Italian Geothermal Union (Conti et al., 2015, Conti et al., 2016). The following definitions hold:

- "Geothermal capacity" is the maximum instantaneous geothermal energy deliverable by the system under well-defined and declared operational conditions;
- "Energy" or "Production" refer to the amount of geothermal energy delivered to the end-user systems (losses included) over a declared period;
- "Capacity factor" (CF) is the ratio between the actual energy delivered by a system and the maximum theoretical output if operation at full capacity load were indefinitely possible.

The evaluation of the figures is based on the energy balance of each considered system, according to the three reference layouts for direct use of geothermal heat described in Cataldi and Conti (2013), Conti et al. (2015), Conti et al. (2016).

The statistics on the geothermal energy employed in the agriculture, aquaculture, balneology, and industrial sectors are based on the data reported in GSE (2018b). For district heating systems (DHs) we refer to the data declared by systems owners and collected by AIRU (2019) and UGI. Finally, statistics on ground-source heat pumps (GSHPs) are based on the data reported in GSE (2018b) and EurObserv'ER (2018), according to the methodology proposed in the European Decision 2013/114/EU. The adopted methodology refers to the prescriptions given by the European Decision 2013/114/EU that considers both electrically and thermal driven heat pumps. Only the heating service is taken into account.

When it was not possible to obtain the actual data, the statistics have been estimated according to available information, some rational considerations, suitable capacity factors (CF), and/or equivalent full load hours of operation (EOHs).

For instance, there is no data on the capacity installed in the agriculture, aquaculture, balneology, and industrial sectors. Therefore, we used the same CF values of previous country reports and the global average values suggested by Lund and Boyd (2015).

7. STATUS OF GEOTHERMAL APPLICATIONS AND THERMAL PRODUCTION

We use for this section the most recent official data, which refer to December 2017 (GSE, 2018b).

The situation of direct uses in Italy is presented in Tables C, D1, D2, E, following the scheme required by the EGC2019 organizing committee. In Tables 1-2 and Fig. 5-6 we show data according to the established UGI methodology.

At the end of 2017, the total installed capacity exceeds 1400 MW_{th}, with a corresponding heat utilization of 10915 TJ/yr (Fig. 5-6). Space heating – DHs and individual systems - is the main sector of utilization in terms of both installed capacity (~ 52%) and energy use (~ 42%). Thermal balneology is the second sector, representing ~32% for both installed capacity and energy use; fish farming holds the third share of the total energy use (~18%), but only 9% of the total installed capacity. Heat utilization for agricultural applications, industrial processes and minor uses amounts to less than 8% of the total.

If we refer to the heating power available for the end-user system (i.e. the condenser output), the nominal thermal power of ground-source heat pump systems is almost 780 MW_{th} (GSE 2018b, EurObserver 2018). It is worth recalling that GSHP statistics refer to the evaporator of the HP units as it is considered as the reference point to evaluate the actual geothermal contribution for heating operation. Therefore, the above-mentioned value of 780 MW_{th} corresponds to about 530 MW_{th} in terms of geothermal installed capacity (i.e., nominal thermal power at the evaporator). The geothermal energy exploitation exceeds 3200 TJ/yr (see Table D1). The values at the condenser (i.e. the useful power/heat delivered to the end-user system) are reported in Table E. As already-mentioned, cooling operation is not accounted.

GSHPs account for 38% of the total installed capacity and some 30% in terms of energy. DHs deliver about 8% of the total geothermal heat. The average CFs of both GSHPs and DHs range around 0.19, while the total geothermal annual CF is equal to 0.24 by reason of the high equivalent working hours of fish farming (CF=0.49), industrial processes (CF=0.28) and agricultural uses (CF=0.28).

Note that the large groundwater heat pumps utilized in DH systems, two in Milan (30 MW_{th}) and one in Bagno di Romagna (1.6 MW_{th}) are accounted within the DH sector in Table C1.

8. THERMAL PRODUCTION DEVELOPMENT

8.1 Evolution of production in the years 2010-2017

Since we are close to the end of the decade, we present a short summary of the evolution of thermal applications in Italy since 2010, as summarised in Table 2.

- Installed capacity has increased from ~ 1000 MW_{th} to more than 1400 MW_{th}, with an average annual growth rate of about 5%/yr. The increase is mainly due to GSHP installations that have more than doubled their capacity: from ~ 250 MW_{th} to 530 MW_{th}. The corresponding average annual growth rate is ~ 11%/yr. The DH sector has also experienced a significant increase, with an annual growth rate of more than 11%/yr in terms of additional capacity;

- Geothermal energy use has increased from about 8700 TJ/yr to more than 10900 TJ/yr, with an annual growth rate of ~ 3%/yr. Again, the higher increase has occurred in the space heating sector, i.e. GSHP (+12%/yr) and DH networks (+6%/yr);

- With respect to a substantial growth in both installed capacity and total energy use, the overall annual CF has decreased of 10% (-1.5%/year) since 2010. This is ascribable to a significant drop in DH equivalent working hours (-32% in total), while GSHP CFs grew of 5% in total.

- The last 7 years has registered a reshaping in the geo-heat utilization (see Fig. 7-8). Space heating has become the first utilization sector, growing from ~ 2600 TJ/yr in 2010 (corresponding to the 30 % of the total geo-heat utilization) to ~ 4560 TJ/yr at the end of 2017 (42% of the total geo-heat utilization). As above-mentioned, this is mainly due to the notable increase of GSHP applications and DH networks (see Fig. 7). Thermal balneology, which stood out as the first sector of utilization in 2010, has slightly reduced its relevance because of the economic crisis that has diminished the customers number and the overall wellness market till 2015 (Becheri and Quirino 2012). Since the last two years we have seen a modest recovery of the balneology sector, with a new increase in the energy use. GSHPs have more than doubled both in terms of installed capacity (from ~250 to over 530 MW_{th}), and geothermal energy utilization (from 1500 TJ/yr to 3265 TJ/yr). At the end of 2010 they accounted for only 17% and 25% of the energy use and installed capacity, respectively, whereas in 2017 they ranged around 30% and 38%, respectively, with an average annual growth rate of 12% and 11%.

Despite the overall rising trend, in the past seven years the geo-heat utilization growth has not been uniform (see Fig. 7-8). The steepest growth (+7.6%/yr), mainly ascribable to the expanding market for space heating, was registered in the years 2010-2012. The years 2013 and 2014 saw a substantial increase of industrial process (+16%/yr), space heating (+10.9%/yr) and agricultural applications (+6.5%/yr). In 2015, instead, it is reported a slight decline in the whole sector productivity (-5%), despite a large increase in DHs installed capacity (+77%) and consequent energy use (+20%).

In the last two years (2015-2017) the thermal applications have grown again in terms of both capacity (+1.6%/yr) and energy use (+1.8%/yr).

Table 1: Summary table of geothermal direct heat uses as of 31 December 2017 in Italy.

Sector of application	Capacity (MW_t)			Energy (TJ/yr)			Capacity Factor		
	Total	**GSHPs**	**DHs**	**Total**	**GSHPs**	**DHs**	**Total**	**GSHPs**	**DHs**
Space heating	739	515	149	4566	3165	853	0.20	0.19	0.19
Thermal balneology	456	-	-	3501	-	-	0.24	-	-
Agriculture uses	80	13	-	656	75	-	0.26	0.18	-
Fish farming	130	-	-	2019	-	-	0.49	-	-
Industrial process heat + minor uses	20	4	1	174	25	10	0.28	0.20	0.32
TOTAL	**1424**	**532**	**150**	**10915**	**3265**	**863**	**0.24**	**0.19**	**0.19**

Table 2. Development of geothermal direct uses in Italy during the 7-year period 2010-2017

Sector of application	Capacity (MW_t)			Energy (TJ/yr)			Capacity Factor		
	Total	GSHPs	DHs	Total	GSHPs	DHs	Total	GSHPs	DHs
Space heating	+88%	+115%	+119%	+75%	+126%	+45%	-6%	+5%	-32%
Thermal balneology	+9%	-	-	+1%	-	-	-7%	-	-
Agriculture uses	+16%	0%	-	+14%	0%	-	-1%	0%	-
Fish farming	+7%	-	-	+5%	-	-	-2%	-	-
Industrial process heat + minor uses	+40%	0%	-	+63%	-	-	+16%	0%	-
TOTAL	**+40%**	**+107%**	**+120%**	**+26%**	**+118%**	**+46%**	**-10%**	**+5%**	**-32%**

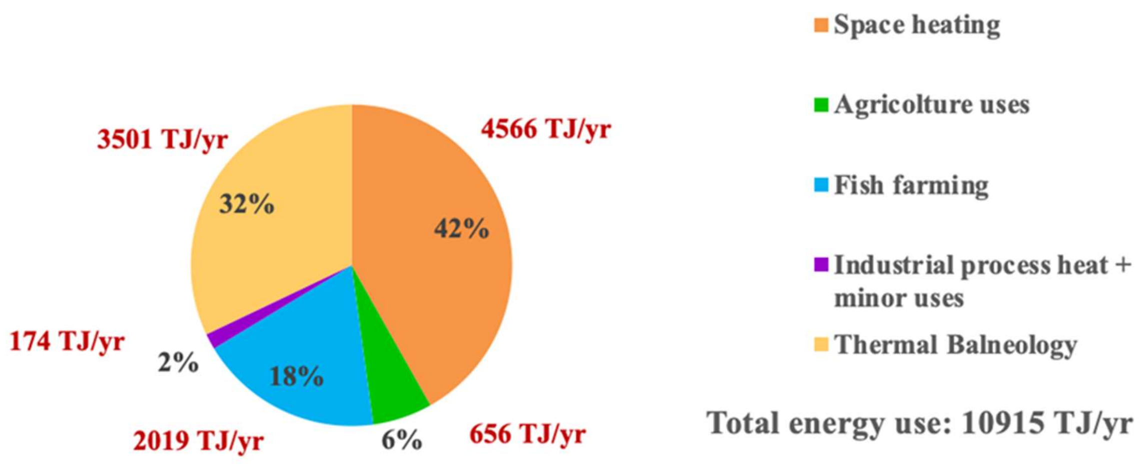

Figure 5: Share of geothermal energy utilization of direct uses in 2017 in Italy.

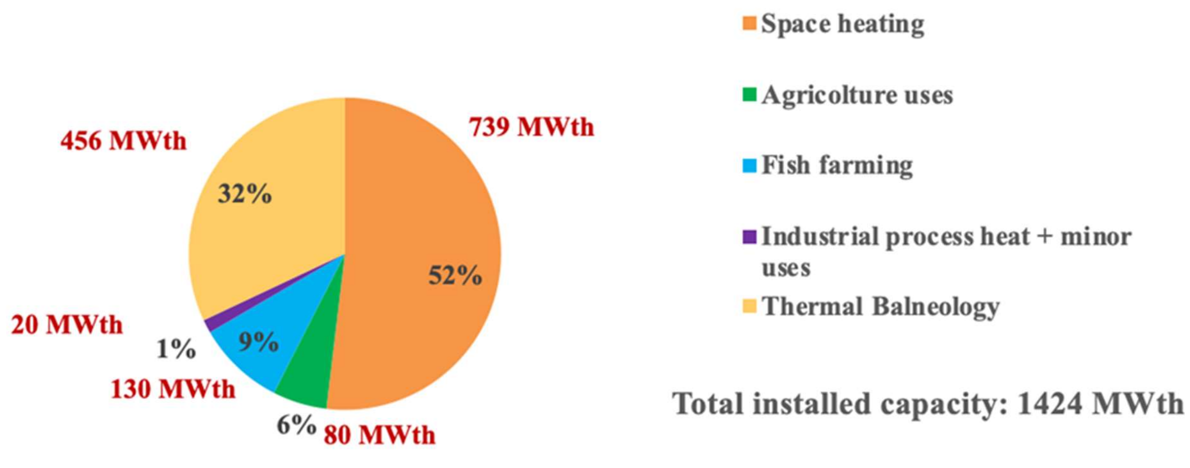

Figure 6: Share of geothermal installed capacity of direct uses of geothermal heat in 2017 in Italy.

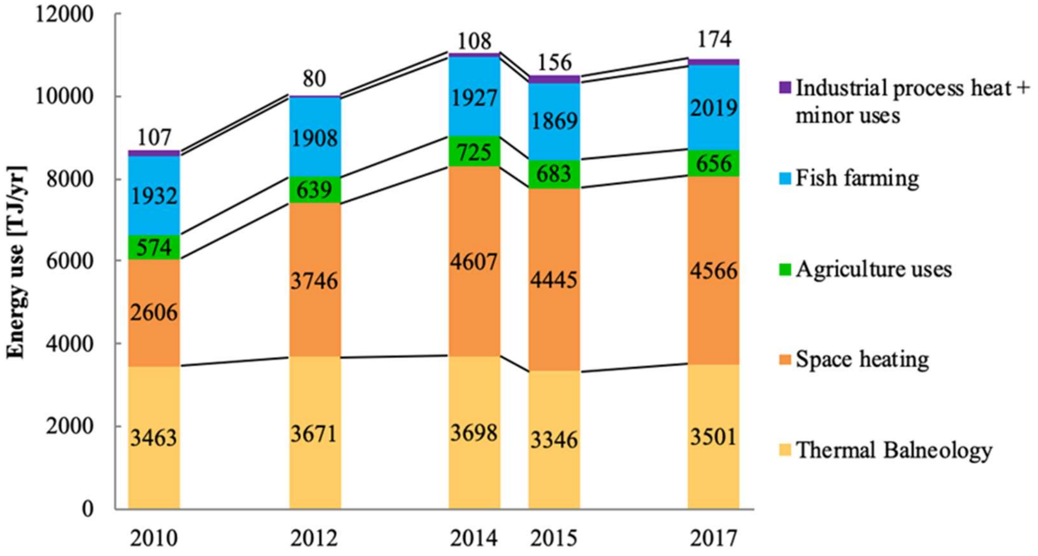

Figure 7: Development of the different sectors of direct uses in Italy (2010-2017).

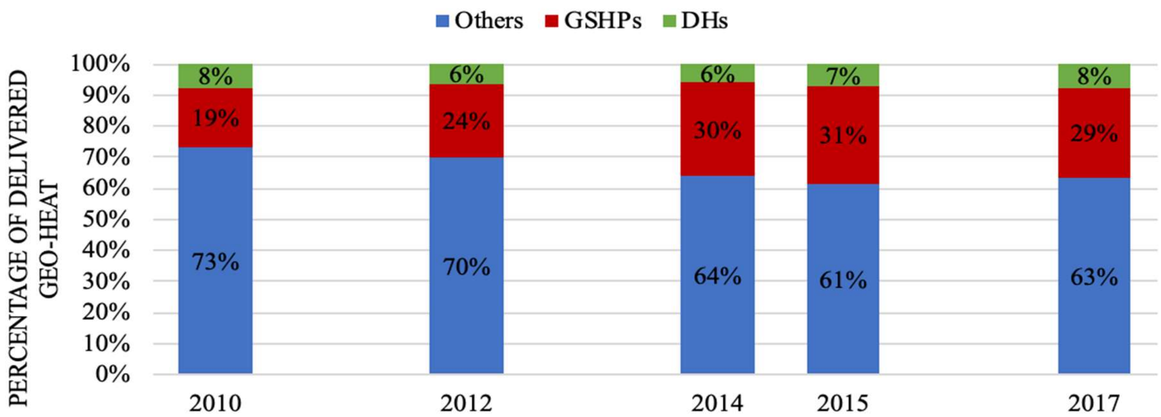

Figure 8: Development of geothermal DHs and GSHPs with respect to the total geo-heat delivered in Italy (2010-2017).

8.2 New development

AIRU (2018) describes four new DH networks in the historical geothermal of Tuscany: two in the Travale-Radicondoli area, in Radicondoli and Chiusdino, and two in Piancastagnaio (Mount Amiata area). One of these networks, La Rota in the Mount Amiata area, was completed in 2017 and provide heating to 19 enterprises, two farming facilities and a religious centre, with the capacity of 4.4 MW_{th}. The network in Radicondoli is reported to start heating the village in the winter 2018-2019, having a capacity of 5.8 MW_{th}. The Piancastagnaio village network development is planned to start by 2019 and to supply 1100 buildings; the Chiusdino network already started its development at the end of 2017 (it is not included in Table D1), with an installed capacity of 6.9 MW_{th}.

Other DH networks are planned in Tuscany, outside the historical geothermal territories: in Castelfiorentino the planned networks will serve 1500 buildings, and in Montecatini the planning has recently started.

9. FOCUS ON GROUND SOURCE HEAT PUMPS STATUS AND DATA

Thermal use of the ground through geothermal heat pumps is difficult to quantify in Italy, a country where the diffusion of air conditioning systems with heat pumps is also well developed, thanks to the high number of cooling units installed. To date there is no national census of geothermal systems with heat pumps, and only a very few local authorities have a plant register. Moreover, the absence of a univocal regulatory framework results in a high fragmentation of the few available data, difficult to compare because they refer to different systems (in some cases the data refer to water-based heat pumps in general, in other cases they refer only to vertical closed-loop systems, in others, finally, to any closed-loop geothermal system).

Official national-scale data are provided by GSE (2018b) and EurObserv'ER (2018): both datasets are estimates, as of today an official register has not being established at national or regional level. In this report we describe data regarding closed-loop systems with vertical geothermal probes installed in the Lombardy Region, the only region in Italy where a register has recorded data since 2010. Since Lombardy Region is also one of the regions where the GSHP market has reached interesting levels, the analysis of these data and related considerations are tentatively extended nationwide, although only on a qualitative level.

9.1 Lombardy Region data for closed loop systems

Lombardy Region established a Regional Register for vertical geothermal probes (closed loop systems) with Regional Regulation no. 7/2010. The Register data indicate that in Lombardy an average of 100-150 new GSHP geothermal plants are installed each year. A total of just 1000 plants with heat pumps and vertical geothermal probes (closed-loop) are recorded by the Register for a total installed capacity of approximately 26.5 MW_{th} in heating and 18.5 MW_{th} in cooling. The average power of individual systems is about 25 kW in heating and 17.5 kW in cooling.

Fig. 9 shows the yearly distribution of vertical geothermal probes surveyed by the Register. There is a relative negative trend in general, although most probably the high values of the first 3 years are partly due to the registration of plants built in the years preceding 2010. A total of 4580 vertical geothermal probes with an average depth of 115 meters are recorded.

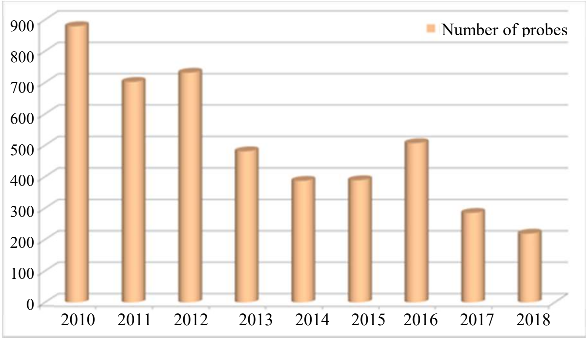

Figure 9: Number of probes recorded per year in the Lombardy Region Register.

It is interesting to observe the distribution of GSHP plants in the area (Figs. 10-12). The Milan Metropolitan Area and neighboring provinces show the highest concentration. In general, there is a large diffusion of GSHP plants in cold areas, with a higher heating requirement compared to cooling.

In Lombardy, the prevalent use of GSHP plants is for heating, especially in the areas of the northernmost provinces where the diffusion of plants is larger, whereas in the southernmost part of the Region GSHP plants are less common and are used at the same extent for heating and cooling requirements.

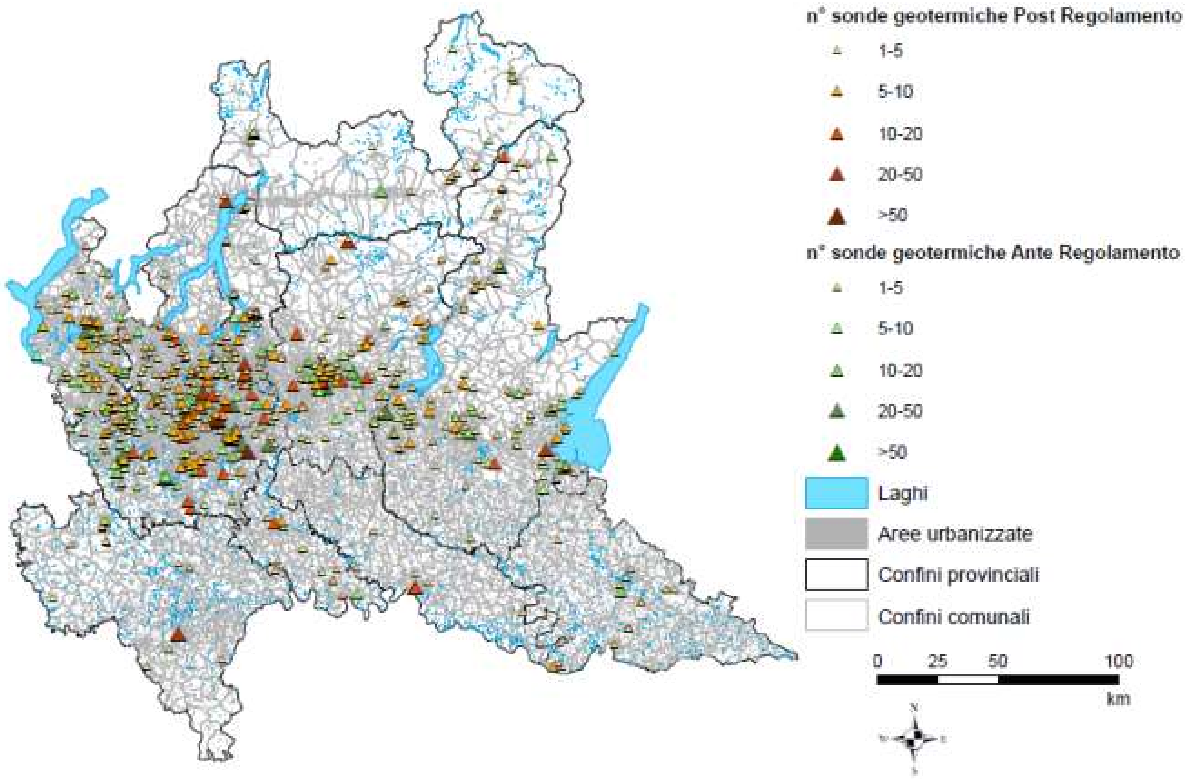

Figure 10: Map of plants in Lombardy

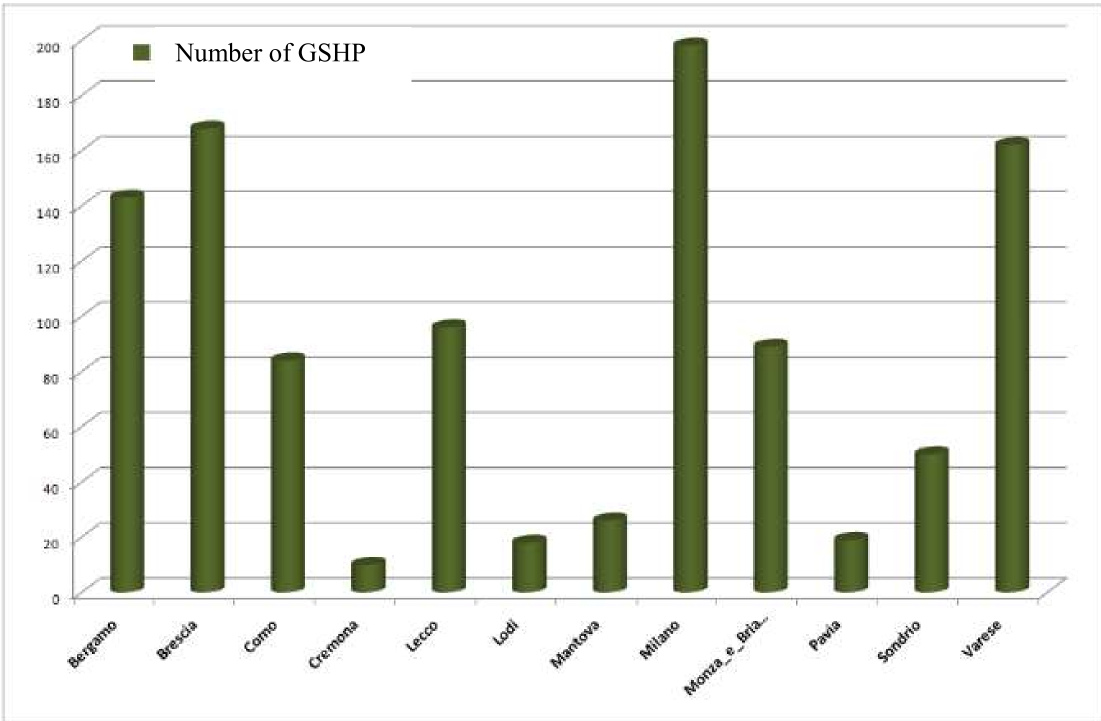

Figure 11: Distribution of GSHP plants in the 12 provinces of Lombardy

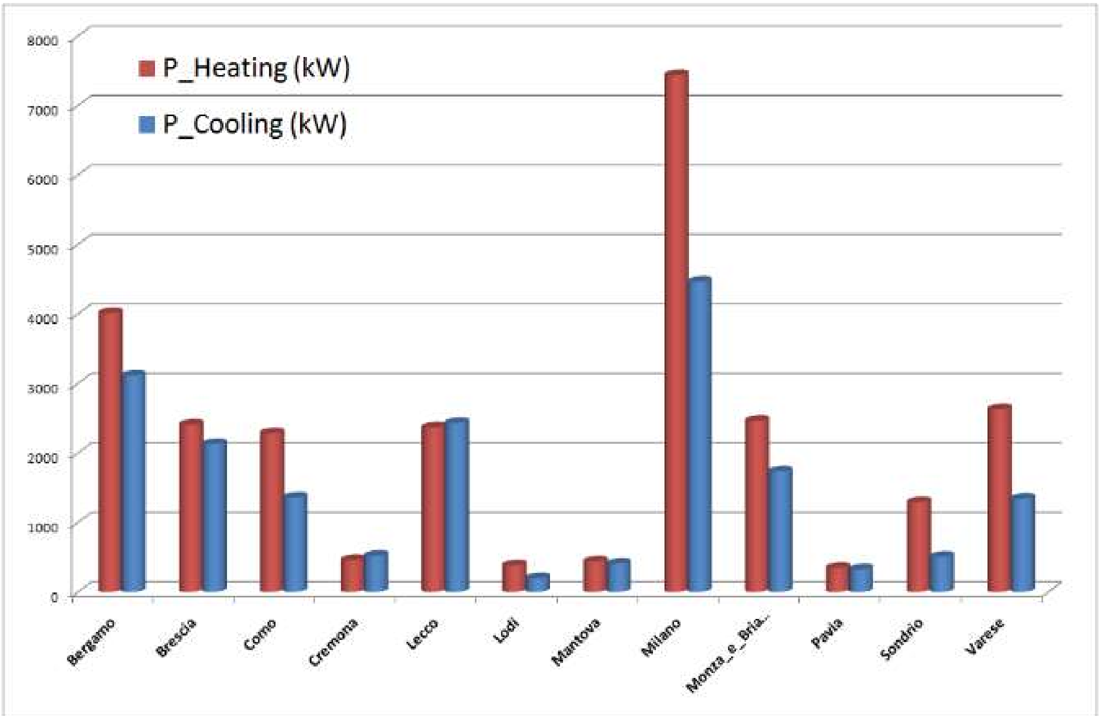

Figure 12: Total thermal power installed (heating and cooling), divided by province.

9.2 Data from EurObserv'ER and GSE

The document recently published by EurObserv'ER (2018) refers to market data for the year 2017. With regard to low enthalpy geothermal the document reports the number of geothermal heat pump units sold per year in each country. The data is mainly constructed through a collection of information from the main heat pump manufacturers and does not reflect official data by the central government or by the territorial bodies due to the difficulty of obtaining useful and homogeneous data, as already mentioned.

The figure indicated for Italy is 860 GSHP units sold in 2017, practically the same as in 2016, and includes open-loop systems.

The figure is particularly low when compared with the volumes for other countries that have a developed and consolidated market (Sweden, Germany, Finland, Austria, France, Denmark, etc.) or where GSHP plants are spreading rapidly (Poland, The Netherlands, United Kingdom, Belgium, etc.).

GSE (2018b) reports the total amount of heat pumps data, most of which are in aggregated figures, including air-air, water-air and geothermal (closed-loop) systems. Only the energy production is subdivided, and the report shows that geothermal closed-loop systems provides 907.14 GWh, representing 2.94% of the total production from heat pumps in Italy. Water based systems, including geothermal open-loop systems, produced on 2017 104.67 GWh, i.e. 0.34% of the total energy production from heat pumps in Italy.

GSE data, as those from EurObserv'ER, are based on information from producers and sellers of heat pumps, and the production is an estimation based on technical characteristics of the used systems.

ANIGHP estimates a total annual market of 1000/1200 plants (including open loop systems) with an average power of about 30 kW and a turnover of about 80-90 million Euros. This is clearly still a niche market, currently destined for a range of medium-high customers, both in financial and environmental-awareness terms.

10. SUPPORT AND MARKET

The Italian Energy Strategy released in 2017 (MISE, 2017) does not forecast any specific increase or promotion of heat production from geothermal sources, and vaguely refers to the will of expanding heat pump uses and district heating infrastructure.

The promotion of the use of RES in heating and cooling is achieved in Italy by tax relief of 55% on RES technologies installation costs (the so-called “Conto Termico”, i.e. Thermal Account), and as part of a wider measure to promote energy savings in the building sector. This latter consists of: 1) for new buildings which are not yet fully operational, the obligation to cover a quota (50%) of their energy needs for domestic hot water with renewable sources; 2) for existing buildings, the possibility of deducting 55% of the costs incurred for energy retrofit operations from personal income tax (IRPEF) or corporate income tax (IRES) obligations (so-called “Ecobonus”).

Since 1998, tax incentives were also introduced for the benefit of users connected to district heating networks fed by geothermal sources. This mechanism pays the end user an incentive for the energy provided by district heating networks fed by geothermal sources, which was 25.8 €/MWh up to 2014, when it was reduced to 21.95 €/MWh. Moreover, there is an incentive of approximately 21.00 €/kW_{th} installed in substations to partially cover the connection costs.

11. DISCUSSION AND CONCLUSION

Beside the development of Enel Green Power, there are actually no other leases in development in Italy, although since 2010, date of the liberalization of geothermal resource exploitation for power generation, about 120 new permit requests have been issued. Ten of those are permits dedicated to “Research for geothermal Resources finalized to the test of Pilot Plants”, with nominal power up to 5 MW.

Currently, 34 Geothermal Research Permits have been released, synthetically listed as follows:

- Two of them, located in Tuscany, are applying for the concession;
- Seven are currently applying for the authorization to realize exploratory wells (5 in Tuscany and 2 in Latium;
- One has obtained the authorization to realize 2 exploratory wells (Tuscany);
- All the other Requests are still in the investigation phase;
- 20 Permit Requests in Latium are still waiting the final advise for the awarding.

Two Pilot Plants obtained the EIA acceptance and are waiting for the final approval from both Region Administration and MISE (Ministry for Economic Development).

It appears that the development for geothermal electricity generation in Italy is rather slow. There are many difficulties: time for authorization is very long and unpredictable and electricity tariff are often not guaranteed for sufficiently long time, so that business plans imply various risks. Actually, support schemes for geothermal are very limited in Italy, and the recent exclusion of geothermal energy from the bids for incentive schemes offered to RES power plants adds further difficulty to the development.

Regarding the direct uses of geothermal heat, the lack of effective support schemes and regulation probably concurs to the very slow growth of geothermal production here described for Italy. The situation is particularly evident for geothermal district heating systems, which could contribute so much to residential heating&cooling demand, and for GSHPs, that were expected to grow at a much higher pace and whose technology is well known and established in numerous other countries.

Most probably the slow increase of geothermal application of heat production and, in particular, of DHs is due to the combination of two aspects: incomplete information related to geothermal energy and the unpredictable long time for the authorization of deep geothermal system development. The lack of official information regarding exact production, number of installations, as well as employment in the thermal sector, and of a comprehensive and harmonized survey of geothermal potential of the Italian territories, limits the possibility to emphasize the benefit of the technologies for the society. This limit could be overcome only with the help of a regulation enforcing such data collection. Moreover, although law prescribes that authorization requests should be answered within a few months, the request for clarifications and further analyses is often iterative, and the whole process may take years, contributing to the high level of risks that characterize the geothermal sector.

Other barriers appear to hinder the development of the GSHP sector, the first one being related to the regulatory framework. While on the one hand Legislative Decree 28/2011 has finally recognized the positive role of GSHP systems, and the contribution of policies to combat climate change and to enhance energy efficiency, on the other hand the issuing of the so-called "*posa-sonde*" (“*geothermal heat exchanger installation*”) Ministerial Decree is necessary to define the guidelines on the simplified procedures for the authorization of closed-loop geothermal plants. Such decree, whose technical text has been defined in a coordinated effort among the main stakeholders and associations since 2016, still waits its final text and issue.

The second "non-technological barrier" for GSHP is cultural: the technology is still little known compared to other renewable energy sources and sometimes it is even hampered due to a general hostility towards all forms of underground activities that imply perforations and extraction of geothermal resources: in this regard it is considered necessary to make a decisive distinction between “deep geothermal” and “shallow, heat exchange" systems with heat pumps, highlighting the difference in terms of lower risks and potential environmental impacts.

Another obstacle is linked to the lack of incentive systems that are reserved only for the replacement of existing plants (Conto Termico and EcoBonus - which are not always sufficiently attractive for this solution), while no incentives are envisaged for new plants, or tariff concessions for GSHP electricity consumption.

A final barrier is organizational: the sector still lacks a mature supply chain that knows how to promote in a coordinated way the different figures (designers and installers); a precise identification of the professional skills necessary for the realization of GSHP systems is also necessary, both in terms of design and work management, and in terms of drilling and installation of the systems.

At the same time, in the last few years some factors have intervened that are elements of impulse for the diffusion of GSHP systems. First of all, the requisites envisaged by Legislative Decree 28/2011 that set up a gradually increasing share of renewable sources to cover the thermal energy needs of new buildings (intended as the sum of heating, cooling and domestic hot water requirements): this requirement - currently set at 50% - is destined to grow further as a result of the new recently issued renewable directive 2018/2001 which provides for a minimum annual increase of 1.3% in the share of renewables used compared to the coverage of the thermal needs of buildings starting from 2021 and until 2030. The actual plan drives inexorably towards heat-pumped air-conditioning systems powered largely by electricity produced from renewable sources; considering also the strong development of photovoltaics in Italy in the last decade, an increasing demand for heating systems that exploit the photovoltaic energy already produced by the installed systems can be easily envisaged.

Furthermore, the development of innovative technologies and solutions in the field of geothermal systems with heat pumps allows a better diffusion of these systems: today there is a variety of solutions - including hybrid, both in the use of other exchange sources combined with heat pumps, and integration with other energy sources – which makes it possible to evaluate the use of geothermal systems in situations and contexts that until a few years ago precluded their use.

Finally, the last important element driving the use of GSHP systems is the growing interest in the protection of air quality, given the degraded air conditions that are found in many cities in Central and Northern Italy. In many cases the conversion of heating (and cooling) systems that exploit fossil fuels to low-enthalpy geothermal systems (both single and combined with urban district heating networks) is perceived as the simplest and most immediate solution to guarantee an improvement in the air quality in the short-medium term. In this case too, the combination of geothermal systems with other energy renewable sources (for electricity production to power the heat pumps) is perceived as the solution to be promoted for achieving NZEBs (Near Zero Emission Buildings).

In conclusion, it is believed that although the heating&cooling geothermal technologies did not penetrate the market as in other European countries, the conditions are nowadays favorable for an appropriate development, especially for the geothermal heat pump technologies.

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Tables A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total electric power generation	
	Installed Capacity (MW_e)	Gross Production (GWh_e/yr)	Gross Efficient Capacity (MW_e) **	Gross Production (GWh_e/yr) **	Capacity (%)	Production (%)
In operation end of 2018	915.5	6064	117144*	295830*	0.78	2.0
Under construction end of 2018	20.0	140.0				
Total projected by 2020	935.5					
Total expected by 2025	975.5 919.0 ***)	6900 ***				
In case information on geothermal licenses is available in your country, please specify here the number of licenses in force in 2018 (indicate exploration/exploitation if applicable):					Under development: 2	
					Under investigation: 34	

* Data as for December 2017.

** From Terna (2017).

*** From MISE (2017). For 2030 the forecast is 950 MW and 7100 GWh from geothermal energy, with a share of geothermal in total electric power generation of 3.8%.

Table B: Existing geothermal power plants, individual sites

Locality	Plant Name	Year commis-sioned	No of units *	Status	Type	Total capacity installed (MW_e)	Total capacity running (MW_e) (1)	2018 pro-duction (GWh_e/y)
Larderello	Valle Secolo	1991	2 (RI)	O	D	120.0	104.8	929.1
Larderello	Farinello	1995	1 (RI)	O	D	60.0	49.0	488.6
Larderello	Nuova Larderello	2005	1 (RI)	O	D	20.0	16.0	119.1
Larderello	Nuova Gabbro	2002	1 (RI)	O	D	20.0	18.2	148.3
Larderello	Nuova Castelnuovo	2000	1 (RI)	O	D	14.5	14.1	126.3
Larderello	Nuova Serrazzano	2002	1 (RI)	O	D	60.0	43.4	320.9
Larderello	Nuova Sasso	1996	1 (RI)	O	D	20.0	13.1	100.9
Larderello	Sasso 2	2009	1 (RI)	O	D	20.0	16.0	135.5
Larderello	Le Prata	1996	1 (RI)	O	D	20.0	16.9	156.9

Table B (continued): Existing geothermal power plants, individual sites

Locality	Plant Name	Year commis-sioned	No of units *	Status	Type	Total capacity installed (MW$_e$)	Total capacity running (MW$_e$) (1)	2018 pro-duction (GWh$_e$/y)
Larderello	Nuova Monterotondo	2002	1 (RI)	O	D	10.0	7.5	52.0
Larderello	Nuova San Martino	2005	1 (RI)	O	D	40.0	34.3	226.0
Larderello	Nuova Lago	2002	1 (RI)	O	D	10.0	10.1	88.1
Larderello	Nuova Lagoni Rossi	2009	1 (RI)	O	D	20.0	11.8	92.7
Larderello	Cornia 2	1994	1 (RI)	O	D	20.0	11.1	109.9
Larderello	Nuova Molinetto	2002	1 (RI)	O	D	20.0	13.4	95.1
Larderello	Carboli 1	1998	1 (RI)	O	D	20.0	14.7	135.8
Larderello	Carboli 2	1997	1 (RI)	O	D	20.0	14.7	122.5
Larderello	Selva	1997	1 (RI)	O	D	20.0	17.4	68.8
Larderello	Monteverdi 1	1997	1 (RI)	O	D	20.0	16.9	110.6
Larderello	Monteverdi 2	1997	1 (RI)	O	D	20.0	14.7	117.1
Larderello	Sesta	2002	1 (RI)	O	D	20.0	13.0	92.8
Travale-Radicondoli	Nuova Radicondoli	2002	1 (RI)	O	D	40.0	36.4	216.2
Travale-Radicondoli	Nuova Radicondoli Gr.2	2010	1 (RI)	O	D	20.0	18.5	142.0
Travale-Radicondoli	Pianacce	1987	1 (RI)	O	D	20.0	13.0	67.7
Travale-Radicondoli	Rancia	1986	1 (RI)	O	D	20.0	18.2	143.6
Travale-Radicondoli	Rancia 2	1988	1 (RI)	O	D	20.0	18.2	130.2
Travale-Radicondoli	Travale 3	2000	1 (RI)	O	D	20.0	15.3	100.1
Travale-Radicondoli	Travale 4	2002	1 (RI)	O	D	40.0	36.6	196.5
Travale-Radicondoli	Chiusdino 1	2010	1 (RI)	O	D	20.0	18.5	159.9
Mount Amiata	Bagnore 3	1998	1 (RI)	O	1F	20.0	18.8	175.3
Mount Amiata	GruppoBinario Bagnore3	2013	1 (RI)	O	B-OCR	1.0	1.0	6.7
Mount Amiata	Bagnore 4	2014	2 (RI)	O	1F	40.0	38.0	363.5
Mount Amiata	Piancastagnaio 3	1990	1 (RI)	O	1F	20.0	19.2	174.7
Mount Amiata	Piancastagnaio 4	1991	1 (RI)	O	1F	20.0	19.2	171.4

Table B (continued): Existing geothermal power plants, individual sites

Locality	Plant Name	Year commis-sioned	No of units *	Status	Type	Total capacity installed (MW_e)	Total capacity running (MW_e) **	2018 pro-duction (GWh_e/y)
Mount Amiata	Piancastagnaio 5	1994	1 (RI)	O	1F	20.0	19.2	179.2
total						**915.5**	**761.2**	**6064**

Key for status:		Key for type:			
O	Operating	D	Dry Steam	B-ORC	Binary (ORC)
N	Not operating (temporarily)	1F	Single Flash	B-Kal	Binary (Kalina)
R	Retired	2F	Double Flash	O	Other

* In case the plant applies re-injection, please indicate with (RI) in this column after number of power generation units

** Reference Net Capacity.

Table C: Present and planned deep geothermal district heating (DH) plants and other uses for heating and cooling, total numbers

	Geothermal DH plants		Geothermal heat in agriculture and industry		Geothermal heat for buildings		Geothermal heat in balneology and other	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2018	149*	237*	229*	791*	590*	1031*	456*	972*
Under constru-ction end 2018	12.7							
Total projected by 2020	162							
Total expected by 2025	188							

* Data as for December 2017

Table D1: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commis-sioned	CHP	Cooling	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2018 produc-tion (GW_{th}/y)	Geoth. share in total prod. (%)
Toscana	Castelnuovo V.C. (PI) **	1985-2015			12.0	12.0	32.9*	100%
Toscana	Monterotondo M.mo (GR) **	1995			6.4	6.4	6.4*	100%
Toscana	Monteverdi Marittimo (PI) **	2014			6.0	6.0	6.6*	100%
Toscana	Montieri (GR) **	2014			6.0	6.0	5.5*	100%
Toscana	Larderello. (PI) **	2015			5.0	5.0	6.7*	100%
Toscana	Lustignano (PI) **	1996			1.0	1.0	1.7*	100%
Toscana	Montecerboli-S.Ippolito. (PI) **	1996-2013			5.5	5.5	10.4*	100%
Toscana	Pomarance (PI) **	2002-2013			37.0	37.0	50.6*	100%
Toscana	San Dalmazio (PI)**	2002			1.5	1.5	2.0*	100%
Toscana	Serrazzano-I Fani (PI) **	1996-2007			2.5	2.5	5.0*	100%
Toscana	Santa Fiora (GR) **	2006			17.2	17.2	21.3*	100%
Emilia Romagna	Bagno di Romagna (FC)	1983			1.4	7.6	2.5	11%
Emilia Romagna	Ferrara **	1987			14.0	155.5	63.5*	36%
Friuli Venezia Giulia	Grado (GO)	2016			2.3	2.3	0.0	100%
Lombardia	Milan **	2010			30.0	901.5	15.9*	2%
Veneto	Vicenza **	2013			1.0	37.7	5.8*	11%
total					**148.8**	**1204.7**	**236.9***	

* Data as for December 2017

** Data from AIRU 2019

Table D2: Existing geothermal large systems for heating and cooling uses other than DH, individual sites

Locality	Plant Name	Year commis-sioned	Cooling	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2018 produc-tion * (GWh_{th}/y)	Geoth. share in total prod. (%)	Operator
Tuscany	La Rota, Piancastagnaio	2017		4.4	4.4			Enel Green Power
total				4.4	4.4			

* Data as for December 2017

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2018		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2018	15000 * 12800 **	745/532 * 800 **	1270/906 * 907.14 ***	800 *		
Projected total by 2020						

* From EurObserv'ER (2018)
** From GSE, personal communication, include only closed loop
*** From GSE (2018b), include only closed loop

Table F: Investment and Employment in geothermal energy

	in 2018		Expected in 2020	
	Expenditures (million €)	Personnel (number)	Expenditures (million €)	Personnel (number)
Geothermal electric power	85*, **	613*, ** 683*, ***		
Geothermal direct uses				
Shallow geothermal				
total				

* Data as for December 2017
** Enel Green Power data
*** Data from MISE 2018, referred to the year

Table G: Incentives, Information, Education

	Geothermal electricity	Deep Geothermal for heating and cooling	Shallow geothermal
Financial Incentives – R&D	No	No	No
Financial Incentives – Investment	No	No	No
Financial Incentives – Operation/Production	Yes for plants in production before January 2019, actually (April 2019) No	No (only Tax relief, tax credit for increased efficiency in buildings)	No (only Tax relief, tax credit for increased efficiency)
Information activities – promotion for the public	Yes in the Tuscany areas and by associations	Yes in the Tuscany areas and by associations	Yes from research projects and by associations
Information activities – geological information	Yes in the Tuscany areas	Yes in the Tuscany areas	
Education/Training – Academic	Yes (in a few universities)	Yes (in a few universities)	Yes (in a few universities)
Education/Training – Vocational	No (only short courses organized by associations)	No (only short courses organized by associations)	No (only short courses organized by associations)

Key for financial incentives:					
DIS	Direct investment support	FIT	Feed-in tariff	-A	Add to FIT or FIP on case the amount is determined by auctioning
LIL	Low-interest loans	FIP	Feed-in premium		
RC	Risk coverage	REQ	Renewable Energy Quota	O	Other (please explain)